ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

SENSITIVITY ANALYSIS FOR THE OPTIMUM SHELTER LOCATION MODEL

M.Sc. THESIS

Seyedali HOSSEINI MILANI

Department of Geomatics Engineering

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

EN UYGUN GEÇİCİ BARINMA ALANLARININ MODELİ İÇİN DUYARLILIK ANALİZİ

YÜKSEK LİSANS TEZİ

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EKİM 2015

Seyedali HOSSEINI MILANI, a **M.Sc.** student of ITU **Graduate School of Science and Engineering** student ID 501121625, successfully defended the **thesis** entitled "**SENSITIVITY ANALYSIS FOR THE OPTIMUM SHELTER LOCATION MODEL**", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 4 May 2015
Date of Defense : 26 October 2015

To my family,

FOREWORD

First of all, I would like to express my sincere gratitude to my advisor Prof. Dr. Himmet Karaman for his guidance throughout my graduate study. It has been my honor to work with him. During the past two years, he provided me with comfortable environment for research, so that I can fulfill my thoughts without many restrictions. Besides, his words and actions improved my personality features. I am grateful to him for being a great mentor in both scientific and extracurricular aspects.

I would like to give my thanks to members of Geomatics Engineering Department for their sincere help.

I would also like to give special thanks to my friends Dr. Sahand Faraji and Dr. Houman Bahmani for their guidance throughout my graduate study.

Appriciation extended to all of my friends eighter in Istanbul or other places all over the world. With them I was never alone even at the hardest times through this work.

Most of all, I would like to express my never ending love to my mother Shahin Alavi, my father Seyed Reza Hosseini Milani and my sisters Ayda Hosseini Milani and Neda Hosseini Milani for their unconditional supports and care during my whole life.

October 2015 Seyedali HOSSEINI MILANI

ABBREVIATIONS

AHP : Analytical Hierarchy Proccess
AKUT : Arama Kurtarma Derneği (Search and Rescue Association)
CI : Consistency Index
CRR : Cyclic Resistance Ratio
CR : Consistency Ratio
DEM : Digital Elevation Model
DRMC : Disaster Risk Management Cycle
FEMA : Federal Emergency Management Agency
GEA : Global Engineering Alliance
GPS : Global Positioning System
GIS : Geographical Information Systems
GSM : Global System for Mobile Communications
JICA : Japan International Cooperation Agency
NEHRP : National Earthquake Hazards Reduction Program
NGA : Next Generation Attenuation
NGO : Non-Governmental Organizations
MAG : Mahalle Afet Gönüllüleri (Neighborhood Disaster Volunteers)
ODTÜ : Orta Doğu Teknik Üniversitesi (Middle-east Technical University)
OFDA : Office of U.S. Foreign Disaster Assistance
RI : Random Consistency Index
RS : Remote Sensing
TSS : Technical Support Section
UN : the United Nations
UNHCR : the United Nations High Commissioner for Refugees
USGS : United States Geological Survey
WHO : World Health Oraganization

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SENSITIVITY ANALYSIS FOR THE OPTIMUM SHELTER LOCATION MODEL

SUMMARY

GIS (Geographical Information Systems) is one of many information technologies that have transformed the ways engineers and planners conduct research and contribute to society. In the past two decades, these information technologies have had tremendous effects on research techniques specific to geography, as well as on the general ways in which scientists and scholars communicate and collaborate.

A spatial decision support system (SDSS) is an interactive, computer-based system designed to assist in decision making while solving a semi-structured spatial problem. It is designed to assist the spatial planner with guidance in making land use decisions. A system which models decisions could be used to help identify the most effective decision path (T Erden & Coşkun, 2010).

Decision making on alternatives for risk reduction planning starts with an intelligence phase for recognition of the decision problems and identifying the objectives. Development of the alternatives and assigning the variable by decision makers to each alternative is employed to the design phase. The final phase evaluates the optimal choice by comparing the alternatives, defining indicators, assigning a weight to each and ranking them. This process is referred to as Multi-Criteria Decision Making analysis (MCDM), Multi-Criteria Evaluation (MCE) or Multi-Criteria Analysis (MCA). MCDM is performed by choice and prioritization and is defined based on Alternative, Value, Criteria and the Weights on the Criteria (Turan Erden & COKSUN, 2007).

Decision makers historically have indicated that inaccessibility of required geographic data and difficulties in synthesizing various recommendations are primary obstacles to spatial problem solving. Studies have shown that the quality of decisions can be improved if these obstacles are lessened or removed through an integrated systems approach, such as a spatial decision support system (SDSS). In addition, multi criteria decision making (MCDM) and a wide range of related methodologies offer a variety of techniques and practices to uncover and integrate decision makers' preferences in order to solve "real-world" GIS-based planning and management problems. However, because of conceptual difficulties involved in formulating and solving spatial decision problems, researchers have developed multi criteria-spatial decision support systems (MC-SDSS).

Sensitivity analysis, as it is applied to risk assessment, is any systematic, common sense technique used to understand how risk estimates and, in particular, risk-based decisions are dependent on variability and uncertainty in the factors contributing to risk. In short, sensitivity analysis identifies what is "driving" the risk estimates. It is used in both point estimate and probabilistic approaches to identify and rank important sources of variability as well as important sources of uncertainty. The quantitative information provided by sensitivity analysis is important for guiding the

complexity of the analysis and communicating important results (C. M. Z. Erden T., 2010).

In this study, sensitivity analysis has applied to Istanbul optimum shelter location map parameters which are respectively Infrastructure (AL), Accessibility (ER), Hazards (TH), Topography (TO), Capacity (KA), Land Use (AK). Their weights were calculated with AHP that determined weights as AL (17.3%), ER (20.7%), TH (31.3%), TO (9.5%), KA (15.5%) and AK (5.7%). Sensitivity analysis applied to all criteria with only one criterion weight range changes between 0% to 100% and other criteria changes depend on this criterion. Also sensitivity analysis has applied to Sub-Criteria maps parameters which are by the weights as follows, Earthquake Hazard (DP - 7.4%), Tsunami Hazard (TS – 7.4%), Land Slide Hazard (HY – 13.2%), Flooding Hazard (SB – 13.2%), Chemical Hazard (KM – 22.7%), Fire Hazard (YN – 36.1%), GSM Base Stations (IL – 6.3%), Drinking Water (SU – 23.3), Waste Water (KN – 48.9), Electricity Lines (EL – 15.2%), Gas Lines (GZ – 6.3%), Roads and Highways (KR – 54.2%), Marine Ports (DN – 8.5%), Heliports (HV – 14%), Railways (DM – 23.3%).

Turkey is among the countries that are especially vulnerable to natural disasters. Throughout the history, many disasters occurred in the geography where turkey area is located and earthquakes are the most destructive type of disaster that occurs in Turkey. Scientific studies show that Istanbul may face a big scale earthquake in near future. The main axis of these studies is to assess the one of the most important issues is the requirement of temporary shelter for the victims. Establishment of temporary shelters are most widely used method for protecting or sustaining the lives of the victims who may have suffered from disasters, Thus the correct locations for these areas will be determined before earthquake and it will be available for the decision makers to develop strategies to enhance and rehabilitate these areas. The system will also be efficient in post-earthquake situation for evaluating the selected sites. Moreover, it will be available to re-evaluate the efficiency of the shelter locations based on the new conditions that arise because of the earthquake. Integration of GIS with AHP decision-making process, with GIS visualization and analysis that combines the functions and decision-making processes by integrating action is improving the sensitivity analysis. Model parameters has chosen by decision makers thanks to the sensitivity analysis that may follow the general effects changes of the model in terms of productivity and quality will be increased in this way. In this context, GIS, disaster management and spatial decision making methods along with sensitivity analysis followed by an operation, decision-makers will follow more meaningful path in their work, decisions and practices to be applied that will minimize such losses life and financial. By using the sensitivity analysis results decision makers will be allowed to update the criteria simultaneously and new locations based on these optimum conditions will be assessed.

For all types of models with different parameters, in order to data availability this method could be practical by merging GIS and AHP systems. It’s note that, during the analysis process, the local standards must be considered as inevitable term for consideration.

The most important challenge in these kinds of projects is gathering the correct data from the local references; fortunately, the data were provided by my supervisor which are reliable enough.It’s noteworthy that these kinds of data are not easily accessable from local metropolitan municipality directorate of earthquake and ground analysis.

Results of this study can be useful for researchers who want to continue this study, because the results of sensitivity analysis which are reached from this study can be added as a new toolbox in the ArcGIS software to show the limitations of criteria weight values for the users who want to change the weight of criteria and the users who try to get a new or a more complete model of certain criteria.

EN UYGUN GEÇİCİ BARINMA ALANLARININ MODELİ İÇİN DUYARLILIK ANALİZİ

ÖZET

CBS (Coğrafi Bilgi Sistemleri) mühendisler ve plancılar tarafından kullanılan bilgi teknolojilerinden biridir. Son yirmi yılda, bilişim teknolojilerindeki gelişmeler, mekansal kavraların yanı sıra bilim adamları ve akademisyenlerin, iletişim ve işbirliği ile yaptıkları araştırmalar ve araştırma teknikleri konusunda önemli etkiye sahip oldu.

Bir mekansal karar destek sistemi (SDSS) yarı yapılandırılmış mekansal problem çözmek için tasarlanmış interaktif bilgisayar tabanlı bir sistemdir. Bu tarz sistemler, arazi kullanım kararları almak ya da yer seçim alternatifleri sunmak konusunda yardımcı olmak üzere tasarlanmıştır. Model kararları en etkili karar yolunu belirlemek için kullanılabilecek bir sistemdir.

Decision making on alternatives for risk reduction planning starts with an intelligence phase for recognition of the decision problems and identifying the objectives. Development of the alternatives and assigning the variable by decision makers to each alternative is employed to the design phase. The final phase evaluates the optimal choice by comparing the alternatives, defining indicators, assigning a weight to each and ranking them. This process is referred to as Multi-Criteria Decision Making analysis (MCDM), Multi-Criteria Evaluation (MCE) or Multi-Criteria Analysis (MCA). MCDM is performed by choice and prioritization and is defined based on Alternative, Value, Criteria and the Weights on the Criteria.

Bu süreç denir olarak analizi (MCDM) Yapımı Çok Kriterli Karar, Multi-Kriterleri Değerlendirme (MCE) veya Çok Kriterli Analiz (MCA). MCDM seçim ve önceliklendirilmesi tarafından yapılır ve Alternatif, Değer, Kriterleri ve Kriterleri Ağırlıkları dayanarak tanımlanır.

Risk azaltma planlarının yapılması aşamasında karar verme süreci, amaçların tanımlanması ve karar verilecek olan problemin aşamalarının akıllıca farkedilip ayrıştırılması ile başlar. Alternatif kararların geliştirilmesi ve her alternatife karar vericiler tarafından bir değişkenin atanması, işin tasarım safhasında gerçekleştirilir. Son safha, alternatiflerin karşılaştırılması, göstergelerin tanımlanması, ile her bir ölçüte bir ağırlık atanıp sıralanması ile optimum seçimin değerlendirilmesi ile tamamlanır. Bu şüreç Çok-Ölçütlü Karar Verme analizi (MCDM), Çok-Ölçütlü Değerlendirme (MCE), ya da Çok-Ölçütlü Analiz (MCA) olarak adlandırılmaktadır. MCDM seçim ve önceliklendirme ile uygulanıp, alternatifler, onlara ait değerler, ölçütler ve ağırlıkları ile tanmlanır.

Çalışmalar göstermektedir ki, eğer kararların kalitesi iyileştirilebilir ise bu engeller bir mekansal karar destek sistemi (SDSS) gibi entegre bir sistem yaklaşımı ile azaltılabilir veya kaldırılabilir. Buna ek olarak, çok kriterli karar verme (MCDM) ve ilgili metodolojiler geniş bir yelpazede ortaya çıkarmak ve "gerçek dünya" CBS

tabanlı planlama ve yönetim sorunlarını çözmek amacıyla karar alıcıların tercihlerini entegre teknikleri ve uygulamaları sunuyoruz.

Bu risk değerlendirmesi uygulanır olarak Duyarlılık analizi, özellikle, risk esaslı kararlar riskine katkıda bulunan etkenler olarak değişkenlik ve belirsizlik bağlıdır ve risk tahminleri ve anlamak için kullanılan herhangi bir sistematik, sağduyu tekniğidir. Kısacası, duyarlılık analizi, risk tahminleri "itici" ne tanımlar. Bu değişkenlik önemli kaynaklarının yanı sıra belirsizlik önemli kaynaklarını belirlemek ve sıralamak için nokta tahmini ve olasılık Her iki yaklaşımın kullanılır. Duyarlılık analizi tarafından sağlanan nicel bilgileri analiz karmaşıklığını rehberlik ve önemli sonuçlar iletilmesi için önemlidir.

Bu çalışmada, duyarlılık analizleri sırasıyla Altyapı olan İstanbul Optimum barınak yeri harita parametreleri (AL), Erişilebilirlik (ER), Tehlikeler (TH), Topografya (TO), Kapasite (KA), Arazi Kullanım (AK). Onların ağırlıkları AL (% 17.3), ER (% 20.7), TH (% 31.3), TO (% 9.5), KA (% 15.5) ve AK (% 5.7) olarak belirlendi ve ağırlıkları AHP ile hesaplandı. Duyarlılık analizi değişiklikler bu kritere bağlı tek bir kriter ağırlık aralığı 0-100% ile arasındaki değişiklikleri ve diğer kriterlere tüm kriterlerde uygulanır. Tsunami Tehlikesi (TS -% 7.4), Kara Slayt Tehlike (HY -% 13.2), Sel Tehlikesi (- Ayrıca duyarlılık analizi Alt Kriterleri başvurdu, Deprem Tehlikesi (% 7.4 DP) aşağıdaki gibi ağırlıkları ile olan parametreler haritalar SB -% 13.2), Kimyasal Tehlike (KM -% 22.7), Yangın Tehlikesi (YN -% 36.1), GSM Baz İstasyonları (IL -% 6.3), İçme Suyu (SU - 23.3), Atık Su (KN - 48.9), Elektrik Hatları (EL -% 15.2), Gaz Hatları (GZ -% 6.3), Yollar ve Otoyollar (KR -% 54.2), Deniz Limanları (DN -% 8,5), Heliports (HV -% 14), Demiryolları (DM - 23.3 %) göz önünde alınmıştır.

Türkiye doğal afetlere karşı özellikle duyarlı olan ülkeler arasında yer almaktadır. Tarih boyunca pek çok felaketler türkiye alanı bulunan ve depremler Türkiye'de meydana felaketin en yıkıcı tipi olduğu coğrafyada meydana geldi. Bilimsel çalışmalara göre İstanbulun yakın gelecekte büyük ölçekli bir depreme karşı karşıya olduğunu göstermektedir. Bu çalışmaların ana ekseni en önemli konulardan biri kurbanları için geçici barınak ihtiyacı olduğunu değerlendirmektir. Geçici barınaklar kurulması en yaygın korunması veya afetlerden etkilenmiş olabileceğini kurbanların hayatlarını sürdürmek için bir yöntem olarak kullanılmaktadır. Bu nedenle, bu alanlar için doğru yerleri depremden önce tespit edilecek ve karar vericiler geliştirmek ve bu alanları ıslah etmek stratejiler geliştirmek için kullanılabilir olacak. Ayrıca bu sistem, seçilen siteler değerlendirmek için deprem sonrası durum etkili olacak ve deprem nedeniyle ortaya çıkan yeni koşullara göre barınma yerleri yeniden değerlendirmek verimliliği sunulacak. Integration of GIS with AHP decision-making process, with GIS visualization and analysis that combines the functions and decision-making processes by integrating action is improving the sensitivity analysis.

Model parametreleri bu şekilde artırılacak verimlilik ve kalite açısından modelin genel etkileri değişiklikleri takip edebilir duyarlılık analizi, karar vericiler sayesinde tarafından seçmiştir. Bu bağlamda, CBS, afet yönetimi ve operasyon ardından duyarlılık analizi ile birlikte mekansal karar verme yöntemleri, karar vericiler bu tür kayıplar hayatı ve mali minimize edecek işlerini, karar ve uygulamalara daha anlamlı yolu uygulamalı olmak izleyecektir. Duyarlılık analizi sonuçları karar vericilerin kullanarak aynı anda kriterleri güncellemek için izin verilecek ve bu optimum koşullarda dayalı yeni yerler değerlendirilecektir. Veri kullanılabilirliği için farklı parametreler ile modellerin her türlü için bu yöntem CBS ve AHP sistemlerini birleştirerek pratik olabilir. Bu analiz sürecinde, yerel standartlar dikkate kaçınılmaz bir terim olarak kabul edilmelidir. Bu tür projelerin en önemli zorluğu, yerel referanslar doğru veri topluyor; Neyse ki, verilerin güvenilir.Değer veriler bu tür deprem ve zemin analizleri, yerel büyükşehir belediyesi müdürlüğünden kolayca erişilebilir olmadığını vardır, ama bu veriler benim gözetmen tarafından sağlandı. Bu çalışmadan elde ulaşılır duyarlılık analizi sonuçları kullanıcıları için kriterler ağırlık değerlerinin sınırlarını göstermek için kullanılır,ayrica bu sonuçlar ArcGIS yazılımınında yeni bir araç kutusu olarak eklenebilir,Ayrıca bu sonuçlar bu çalışmayı devam etmek istiyen araştırmacılar için yararlı olabilir, kriter ağırlığını değiştirmek isteyenler, ve ya yeni belirli kriterlerin daha eksiksiz bir model almaya çalışın kullanıcıların ağırlığını değiştirmek isteyenler yararlı olabilir.

1. INTRODUCTION

Istanbul lies on an active seismic zone ranging from Java – Myanmar – Himalaya – Iran – Turkey and Greece (Figure 1.1) where many large earthquakes have occurred in the past. Based on worldwide historical earthquake catalogues, Istanbul (Constantinople) has experienced earthquakes equal or greater than intensity 9 at least 14 times from 5th century. This means Istanbul has suffered damages due to earthquakes every 100 years, on average (Segawa, 2004).

For example, Kocaeli earthquake has occurred around the western end of the North Anatolian Fault (NAF), which is extending over 1500 km and across the Marmara Sea where Istanbul faces (Marza, 2008). In 2014, Istanbul has an estimated population of 14.2 million. Istanbul has a population density of 2,523 people per square kilometer (6,530/sq mi), far greater than Turkey's density of 102 people per square kilometer. The most densely populated areas are the southwest, west and northwest of the city center as well as the European side, while the most densely populated district is the Asian side, Uskudar (TURKEY, 2014).

Information gathering to site selection and planning should include local authorities and communities, government offices, educational institutions and UN agencies. UNHCR Headquarters, through the focal point on Geographical Information Systems (GIS), can also support operations with maps, aerial photographs, satellite images and a special geographic database (UN, 2007).

One of the most important determinants in site selection physical planning and shelter is the social and cultural backgrounds of the refugees. In many situations, however, options will be limited and land that meets even minimum standards may be rare. It is therefore wise to put on record the shortcomings of the site and the rationale for its selection (UN, 2007).

According to this information about Istanbul region Temporary shelter sites should be estimated that which area will be safer and more suitable, to be prepared as good as possible to the expected earthquake that will cause inescapable.

Frey et al. (2004) define sensitivity analysis as the assessment of the impact of changes in input values on model outputs (Patil & Frey, 2004). Similarly (Saltelli, A., Chan, K. & Scott, 2000) define sensitivity analysis as the study of how the variation in the output of a model can be apportioned, qualitatively or quantitatively, among model inputs. The answers sought from application of sensitivity analysis should always be clearly listed. The usefulness of sensitivity analysis can then be assessed based on whether the available methods of sensitivity analysis can address the questions under consideration in a manner that is appropriate to the characteristics of the model. Key motivations for performing a sensitivity analysis include identification of key sources of variability and uncertainty in order to facilitate model development, verification, and validation; prioritization of key sources of variability and uncertainty in order to prioritize additional data collection and research; and general model refinement (Patil & Frey, 2004).

In this study sensitivity analysis by using AHP in GIS environment on Istanbul optimum shelter locations map will be performed, also the Intervals for each parameter in the model will be tested.

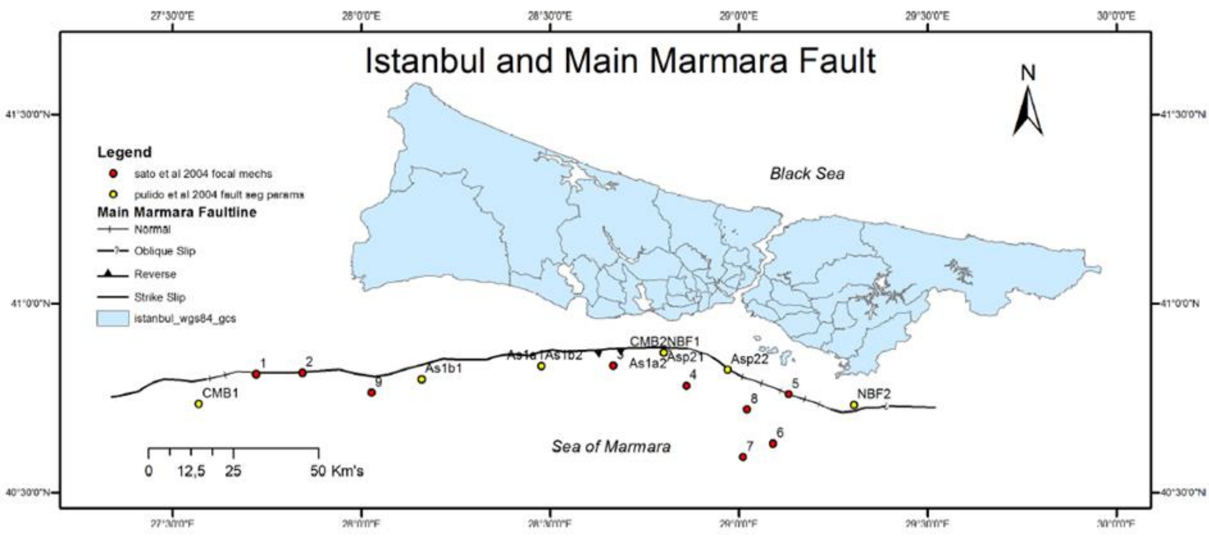

Figure 1.1: Main Marmara fault line and the focal parameter locations.

2. DISASTERS

'Disaster' is defined as a crisis situation causing wide spread damage which far exceeds our ability to recover. Thus, by definition, there cannot be a perfect ideal system that prevents damage, because then it would not be a disaster. It has to suffocate our ability to recover. Only then it can be called as 'Disaster'.

Disasters are not totally discrete events. Their possibility of occurrence, time, place and severity of the strike can be reasonably and in some cases accurately predicted by technological and scientific advances. It has been established there is a definite pattern in their occurrences and hence we can to some extent reduce the impact of damage though we cannot reduce the extent of damage itself (Quarantelli, 1985).

2.1 Types of Disaster

Disasters are classified to two types, which are shown below.

2.1.1 Natural Disaster

These types of disaster naturally occur in proximity to, and pose a threat to, people, structures or economic assets (Figure 2.1). They are caused by biological, geological, seismic, hydrologic, or meteorological conditions or processes in the natural environment (e.g., cyclones, earthquakes, tsunami, floods, landslides, and volcanic eruptions) (VUSSC, 2013).

Figure 2.1: Types of natural disasters

2.1.2 Manmade Disaster

Man-made disasters are specific events where an anthropogenic hazard has come to fruition. An anthropogenic hazard or a human-made hazard can result in the form of a human-made disaster (Disasterium, 2013). An example from Mexican oil spill in 2010 can be seen in Figure 2.2.

Figure 2.2: Oil Spill Mexico 2010

2.2 Earthquake

The Earth – as ecologists always reminds us- is alive, and an earthquake is the unfolding of a series of natural planetary events. An earthquake is just a stretch or a shrug, one normal and expected movement among many. This is simply how the earth behaves (Clague, 2011).

Earthquakes are measured using observations from seismometers. The moment magnitude is the most common scale on which earthquakes larger than approximately 5 are reported for the entire globe. The more numerous earthquakes smaller than magnitude 5 reported by national seismological observatories are measured mostly on the local magnitude scale, also referred to as the Richter scale. These two scales are numerically similar over their range of validity. Magnitude 3 or lower earthquakes are mostly almost imperceptible or weak and magnitude 7 and over potentially cause serious damage over larger areas, depending on their depth. The largest earthquakes in historic times have been of magnitude slightly over 9, although there is no limit to the possible magnitude. The most recent large earthquake of magnitude 9.0 or larger was a 9.0 magnitude earthquake in Japan in

2011 (as of October 2012), and it was the largest Japanese earthquake since records began. Intensity of shaking is measured on the modified Mercalli scale. The shallower an earthquake, the more damage to structures it causes, all else being equal (Ashmita. A., 2013).

2.2.1 Types of Earthquakes

There are three different types of earthquakes: tectonic, volcanic, and explosion. The type of earthquake depends on the region where it occurs and the geological make-up of that region. The most common are tectonic earthquakes. These occur when rocks in the Earth's crust break due to geological forces created by movement of tectonic plates. Another type, volcanic earthquakes occur in conjunction with volcanic activity. Collapse earthquakes are small earthquakes in underground caverns and mines, and explosion earthquakes result from the explosion of nuclear and chemical devices. An illustration of different types of earthquakes can be seen in Figure 2.3.

A tectonic earthquake is one that occurs when the earth's crust breaks due to geological forces on rocks and adjoining plates that cause physical and chemical changes (Claire, 2013).

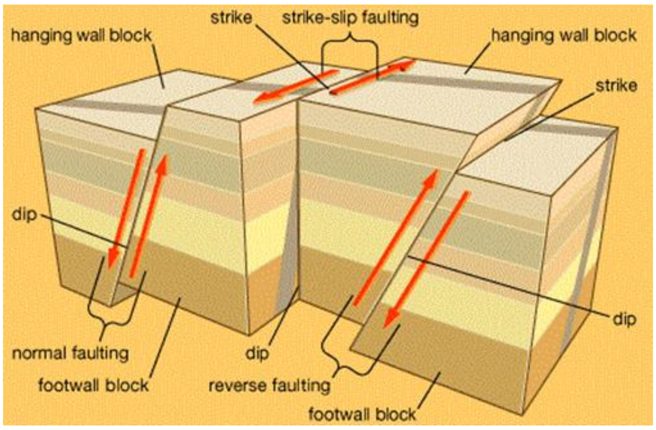

Figure 2.3: Different types of earthquakes and faults (Cauz, 2014)

A volcanic earthquake is any earthquake that results from tectonic forces which occur in conjunction with volcanic activity. Figure 2.4 shows what happens in a volcanic earthquake.

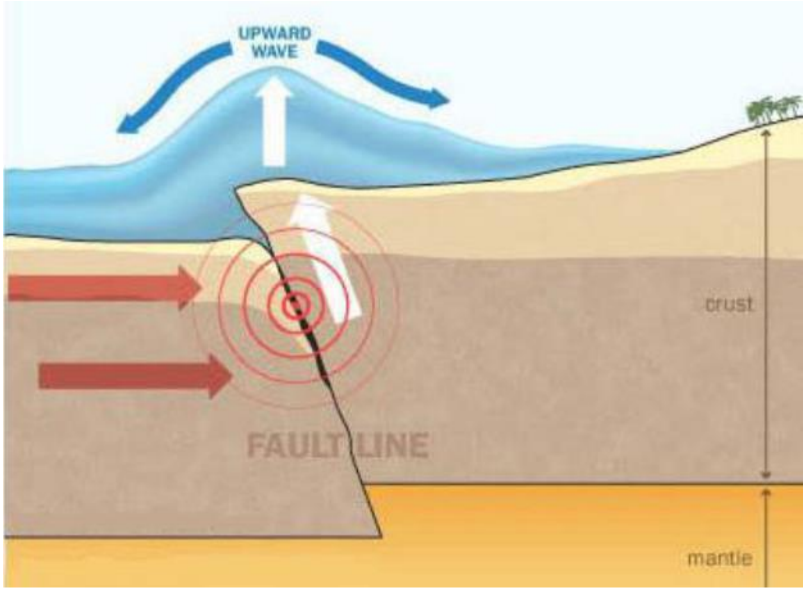

Figure 2.4: Volcanic earthquake

A collapse earthquake is small earthquakes in underground caverns and mines that are caused by seismic waves produced from the explosion of rock on the surface. In Figure 2.5, some damages caused by a collapse earthquake are shown.

Figure 2.5: Collapse earthquake Kobe japan 2005

An explosion earthquake is an earthquake that is the result of the detonation of a nuclear and/or chemical device like Figure 2.6.

Figure 2.6: Explotion earthquake japan 2011

As it is shown in Figure 2.7, there are three different types of faults: Normal, Reverse, and Trans current (Strike-Slip).

Normal faults form when the hanging wall drops down. The forces that create normal faults are pulling the sides apart, or extensional (Karaman, 2008).

Reverse faults form when the hanging wall moves up. The forces creating reverse faults are compressional, pushing the sides together (Karaman, 2009).

Trans current or Strike-slip faults have walls that move sideways, not up or down (Claire, 2013).

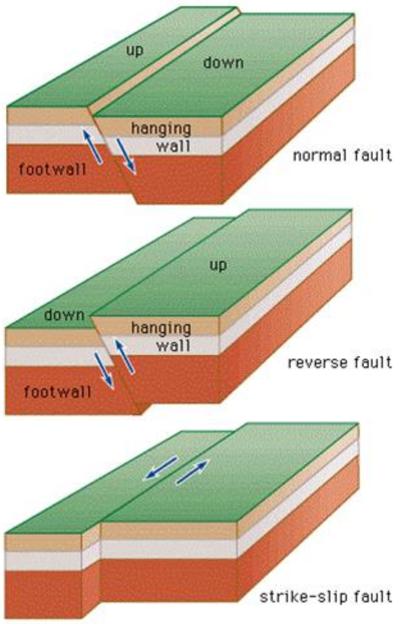

Figure 2.7: Different types of faults

2.3 Disaster Management Cycle

Disaster management is defined as a cycle of activities including mitigation, preparedness, response and recovery. Mitigation efforts refer to those activities which reduce the vulnerability of society to the impacts of disasters. Preparedness efforts refer to those activities which make the government and disaster responders prepare for responding to a disaster, if it occurs. Response refers to the activities necessary to address the immediate and short-term effects of a disaster, which focus primarily on the actions necessary to save lives, to protect property and to meet basic human needs. Relief, rescue, search, firefighting, medical service, permit control, sheltering, evacuation, law enforcement and many others are samples of disaster response activities. Recovery efforts refer to those activities that bring communities back to normal and they should be toward meeting mitigation and preparedness needs. Figure 2.8 shows the cycle of disaster management in 4 sections as can be seen in Figure 2.8: (Mansourian, 2006)

Mitigation - Minimizing the effects of disaster. Examples: building codes and zoning; vulnerability analysis; public education.

- Preparedness - Planning how to respond. Examples: preparedness plans; emergency exercises/training; warning systems.

- Response - Efforts to minimize the hazards created by a disaster. Examples: search and rescue; emergency relief.

- Recovery - Returning the community to normal. Examples: temporary housing; grants; medical care (Vasilescu, Khan, & Khan, 2008).

Figure 2.8: Cycle of disaster management (Naghdi, 2008)

If the disaster is predictable like the earthquake, sheltering the injured people is the major part after the disaster, which is a part of the response phase. In this situation for temporal sheltering of the injured people, the safe areas around the city or the countryside should be recognized as well as the rescue operations. In the next process, the injured people should be transferred to these safe areas by the optimum path. When the disaster is predictable like flood, sheltering the people will be explained in the preparation phase. In other word, people should be carried to safe areas by optimum path before the disaster occurrences (Naghdi, 2006).

2.4 Before a Disaster

Pre-disaster activities those which are taken to reduce human and property losses caused by a potential hazard. For example, carrying out awareness campaigns, strengthening the existing weak structures, preparation of the disaster management plans at household and community level, etc. Such risk reduction measures taken under this stage are termed as mitigation and preparedness activities (Vasilescu et al., 2008).

2.5 During a Disaster

These include initiatives taken to ensure that the needs and provisions of victims are met and suffering is minimized. Activities taken under this stage are called emergency response activities (Vasilescu et al., 2008).

2.6 After a Disaster

There are initiatives taken in response to a disaster with a purpose to achieve early recovery and rehabilitation of affected communities, immediately after a disaster strikes. These are called as response and recovery activities. Some of these cut across both stages (such things as coordination and the provision of ongoing assistance); whilst other activities are unique to each stage (e.g. Early Warning and Evacuation during Emergency Response; and Reconstruction and Economic and Social Recovery as part of Recovery) (Vasilescu et al., 2008).

Disaster management aims to reduce, or avoid the potential losses from hazards, assure prompt and appropriate assistance to victims of disaster, and achieve rapid and effective recovery (Vasilescu et al., 2008).

The disaster management cycle illustrates the ongoing process by which governments, businesses, and civil society plan for and reduce the impact of disasters, react during and immediately following a disaster, and take steps to recover after a disaster has occurred. Appropriate actions at all points in the cycle lead to greater preparedness, better warnings, reduced vulnerability or the prevention of disasters during the next iteration of the cycle. The complete disaster management cycle includes the shaping of public policies and plans that either modify the causes of disasters or mitigate their effects on people, property, and infrastructure. The mitigation and preparedness phases occur as disaster management improvements are made in anticipation of a disaster event. Developmental considerations play a key role in contributing to the mitigation and preparation of a community to effectively confront a disaster. As a disaster occurs, disaster management actors, in particular humanitarian organizations become involved in the immediate response and long-term recovery phases. The four disaster management phases illustrated here do not always, or even generally, occur in isolation or in this precise order. Often phases of the cycle overlap and the length of each phase greatly depends on the severity of the disaster (Vasilescu et al., 2008).

3. SHELTERS

Shelter is likely to be one of the most important determinants of general living conditions and is often one of the significant items of non-recurring expenditure. While the basic need for shelter is similar in most emergencies, such considerations, as the kind of housing needed, what materials and design to be used, who constructs the housing and how long it must last will differ significantly in each situation (UN, 2007).

When locating or planning emergency settlements, their long-term economic, social and environmental impacts on the surrounding area should be carefully considered (Wisner & Adams, 2002).

In many situations, such as in northern Iraq and several countries of Eastern Europe and the former Soviet Union during the 1990s, people may independently seek shelter in buildings such as schools, community centers, offices, sports facilities and even railway carriages and wagons. Such buildings are often also used for organized short-term evacuation centers (Wisner & Adams, 2002).

Buildings used as short-term reception areas should be thoroughly inspected by a suitably qualified person, to ensure that they are not structurally damaged, or sited near potential secondary hazards (Wisner & Adams, 2002). In Figure 3.1 a sample shelters after L’Aquila earthquake is shown.

Figure 3.1: Shelters after L’Aquila earthquake (2009)

3.1 Shelter Area Literature Review

Looking back to other worldwide studies about shelter site selection based on AHP there are some studies like:

GIS-Based Design of Urban Emergency Shelter in Songbei Harbin, which is about Songbei district of Harbin city as study area and flood damage as researching object, GIS spatial analysis is used to suitability analysis of emergency shelter by AHP getting every weight coefficient, which select drainage landscape function area, Songbei residential area and dam as main impacting factors. Finally, it determines three level emergency shelter alternative districts, community level, street level and urban district level (Tongs, 2012).

Comprehensive Evaluation Index System in the Application for Earthquake Emergency Shelter Site, which is aimed to establish earthquake emergency shelter site evaluation index system, make use of analytic hierarchy process method to determine the index weight, using comprehensive fuzzy evaluation method to evaluate and order the shelters in certain areas, and ultimately select earthquake emergency shelters (Chu Y.J, 2010).

3.2 Criteria for Shelter Site Selection

3.2.1 Water

The single most important site-selection criterion is the availability of an adequate amount of water on a year round basis. This most important factor is also commonly the most problematic. A site should not be selected on the assumption that water can be acquired merely by drilling, digging, or hauling. Drilling may not be feasible and may not provide adequate water. No site should be selected where the hauling of water availability should be required over a long period. A professional assessment of water availability should be a prerequisite in selecting a site (OFDA, 1998).

Where water is readily available, drainage is a key criterion. For effective drainage, the entire site should be located above flood level at a minimum of 3 m above the water table, preferably on a gently sloping area. Flat sites can present serious problems for the drainage of waste and storm water. Marshes or areas likely to become marshy or soggy during the rainy season should be avoided. Conditions within the watershed may be a consideration (OFDA, 1998).

3.2.2 Open space

The site must provide a sufficient amount of usable space for the displaced population to engage in communal and agricultural activities, livestock husbandry, or other activities (e.g., recreation, meeting spaces, etc.). Although camp planning should be based on a known design capacity (e.g., shelter and other facilities sufficient for, say, 20,000 people), the possibility always exists that more people may arrive. To the extent possible, the site should be planned to accommodate a major influx of additional people. If the population has been displaced because of civil strife, the site should be removed from areas of potential conflict (OFDA, 1998).

3.2.3 Accessibility

The site must be accessible by vehicles and close to communication links and sources of supplies and services such as food, cooking fuel, shelter material, and national community services (OFDA, 1998).

3.2.4 Land Rights

The land should be exempt from ownership, grazing, and other uses by local populations. Using such land can be a cause of local resentment. Authorities proposing the site may be unaware of customary rights exercised by local populations. Sites are often provided on public land by the government. Any use of the land must be based on formal legal arrangements in accordance with the laws of the country (OFDA, 1998).

3.2.5 Surface Area

The site must allow sufficient usable space for the refugees. WHO recommends 30 sq. meters plus the necessary land for the agricultural activities and livestock. More refugees may arrive and it is essential that the site allows for a major expansion beyond the area theoretically required for present numbers. It is particularly important that having allowed space for expansion, this is safeguarded until really needed. Otherwise the initial settlement will occupy all the space, and major upheavals of existing arrangements will be necessary as more refugees arrive (UN, 2007).

3.2.6 Topography and Drainage

The whole site should be located above the flood level preferably on a gently sloping area. Flat sites can present serious problems for the drainage of waste and storm water. The watershed of the area itself will be a consideration (UN, 2007). for temporary planned camps the site gradient should not exceed 6%, unless extensive drainage and erosion control measures are taken, or be less than 1% to provide for adequate drainage. Drainage channels may still be required to minimise flooding or ponding. The lowest point of the site should be not less than 3 metres above the estimated level of the water table in the rainy season. Ground conditions should also inform the locations of toilets and other facilities and hence the planning of settlements e.g. fissured rock may disperse toilet waste widely; fine clays provide poor percolation and the early failure of toilet pits; volcanic rock makes the excavation of toilet pits difficult (Oxfam GB., 2004).

3.3 Standards

In addition to meeting the immediate needs, planning should take into consideration the long-term provision of services even if the situation is expected to be temporary (UN, 2007).

Decisions on site selection and camp planning are very difficult to reverse, therefore seek technical support, for example avoiding high population density congestion in settlements and in accommodation; avoid very large settlements; refugee camps should normally be considered as the last option, involving refugees in all phases of settlement layout and shelter design and construction (UN, 2007).

When establishing post-disaster shelter recovery and reconstruction operations, site selection is the most consequential decision that must be made. No other decision has as profound and lasting an impact on the lives of victims or on the likelihood of long-term project success and sustainability (Haddow G., Copolla D., 2010).

The development and provision of standard site selection criteria, which dictates assessment processes and suitability decisions, will increase speed and efficiency of site selection and reduce variance among implementing agencies' efforts (Haddow G., Copolla D., 2010).

Site selection needs to consider not only the viability of the individual home, but also how construction on that site will subsequently affect the community as a whole (including how the site will affect infrastructure access and recovery decisions) (Benson, 2011).

Long-term housing reconstruction plans will need to consider a menu of possible options given the differences in each community's and each household's circumstances (U. S. Department of Homeland Security, 2009).

Site selection should focus on keeping recipients as close to their land as is possible given risk reduction goals (Benson CH,Twigg J, Rossetto T, 2007).

3.3.1 Standards for shelters

When existing buildings are not available, one possibility is to use tents or make shift shelters made of plastic sheets, tarpaulins, or local materials, such as palm thatch, in a secure location where water, sanitation and food can be provided. Emergency settlements for refugees and displaced people need to be established rapidly. However, they may be in service for months or even years, and it is usually impossible to know at the outset of an emergency how long the emergency settlement will exist. Therefore, the measures listed below are designed to provide healthy living conditions for disaster-affected people in both the short term and the long term (Oxfam GB, 2004).

- The site should be free of major water-related hazards.
- The topography of the land should permit easy drainage and the site should be located above flood level. Ideally, the site should have a slope of 2–4% for good drainage, and not more than 10% to avoid erosion and the need for expensive earth-moving for roads and building construction.
- Areas adjacent to commercial and industrial zones, exposed to noise, odours, air pollution and other nuisances should be avoided.
- Areas sufficiently close to blocks or rows of shelters should be identified for sanitation and waste management. The residential area of the camp should face the prevailing wind to avoid odors from latrines.

- There should be ample space for the people to be sheltered and for all the necessary public facilities such as roads, firebreaks and service areas.
- To facilitate the management and control of communicable diseases, camps should hold no more than 10000–12000 people, or should be subdivided into independent units of no more than 1000 people.
- Drainage ditches should be dug around the tents or other shelters and along the sides of roads, especially if there is a danger of flooding.
- The site should be provided with at least two access roads for reasons of security and to reduce the risk of the site being cut off due to floods or other problems with roads.
- There should be a minimum of $3.5m^2$ per person inside the shelter in warm climates where cooking is done outside, and $4.5–5.5m^2$ per person in cold climates where cooking is done inside the shelter.
- The site chosen should be within reasonable distance of an ample source of good water and, ideally, near some high ground from which water can be distributed by gravity. No one should have to walk more than 500 meters to a water point, and there should be at least one water point for every 250 people.
- Where there is no piped water, water tanks should be installed on both sides of the road (Oxfam GB, 2004).

3.4 Longer-Term Issues for Emergency Settlements

When emergency settlements exist for more than a few weeks, a number of social, environmental and health issues need to be considered to ensure that the health and wellbeing of the settlement population are sustained and that long-term costs of maintaining the settlement infrastructure and services are kept under control. Some of the short term risks to health may be managed during the emergency phase, but when communities are obliged to remain in emergency settlements for a long time, a number of psychosocial and other health problems associated with alienation, overcrowding, and loss of control and purpose, demand special attention (Oxfam GB, 2004).

4. GEOGRAPHIC INFORMATION SYSTEMS (GIS)

A Geographic Information System (GIS) is an organized collection of computer hardware, software, geographic data, and personnel designed to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. This system allows users to perform very difficult, time consuming, or otherwise impractical spatial analysis (Esri, 2014).

4.1 GIS and the Disaster Management Cycle

4.1.1 Planning

The most critical stage of disaster management is the realization that there is a need for planning based on the risk that is present. The extent to which lives and properties will be spared the adverse effects of a disaster is dependent on the level of planning that takes place and the extent to which technology has been incorporated in planning efforts. GIS is useful in helping with forward planning. It provides the framework for planners and disaster managers to view spatial data by way of computer based maps (Carrillo, 2010).

4.1.2 Mitigation

The use of GIS in disaster management can help with structural and non-structural mitigation. GIS allows you to spatially represent areas at risk and the level of risk associated with particular hazard, which can be a guide in decision making. It will facilitate the implementation of necessary mechanisms to lessen the impact of potential emergency (Carrillo, 2010).

With GIS , disaster managers are in a better position to determine the level of mitigate structures that should be in place given the vulnerability of an area or population (Carrillo, 2010).

4.1.3 Preparedness

As a tool, GIS can help with the identification and location of resources and "at risk" areas. It establishes a link between partners and critical agencies, which allow disaster managers to know where relevant partner agencies are stationed. In the context of disaster management, GIS maps can provide information on the human resources present in an Emergency Operation Centre as well as on the ground personnel such as security, health providers and other key responders. This is particularly useful since the technology can help with strategic placement of emergency personnel where it matters most. GIS helps to answer the question of who is to be based where and at what phase during the emergency. It can help to determine whether or not road infrastructure and communications networks are capable of handling the effects of disaster and, if necessary, guide in the placement of resources (Carrillo, 2010).

4.1.4 Response

GIS technology can provide the user with accurate information on the exact location of an emergency situation. This would prove useful as less time is spent trying to determine where the trouble areas are. Ideally, GIS technology can help to provide quick response to an affected area once issues are known. In the case of a chlorine explosion for example, GIS can indicate the unsafe area as well as point rescue workers to resources that are closest to the affected areas. GIS can be used as a floor guide for emergency response to point out evacuation routes, assembly points and other evacuation matters (Carrillo, 2010).

4.1.5 Recovery

Mapping and geo-spatial data will provide a comprehensive display on the level of damage or disruption that was sustained as a result of the emergency. GIS can provide a synopsis of what has been damaged, where, and the number of persons or institutions that were affected. This kind of information is quite useful to the recovery process (Carrillo, 2010).

4.2 ArcGIS Methods

4.2.1 Classification

Defining the class ranges and breaks-the high and low values that bracket each class-will determine which features fall into each class and thus what the map will look like. Changing the classes creates very different-looking maps. Generally,the goal is to make sure features with similar values are in the same class (Minami, Kinoshita, Kamoshida, Tanimoto, & Tabata, 1999).

Two key factors for classifying the data are the classification scheme which is used and the number of classes are created. If the data is wellknown, they could be manually defined by classes (Minami et al., 1999).

Alternatively, ArcMap can classify the data using standard classification schemes. The four most common schemes are natural breaks, quantile, equal interval, and standard deviation (Minami et al., 1999).

The following sections go through the classification method:

Layer properties →Symbology

By choosing classify the classification method could be chosen from the opened window like Figure 4.1:

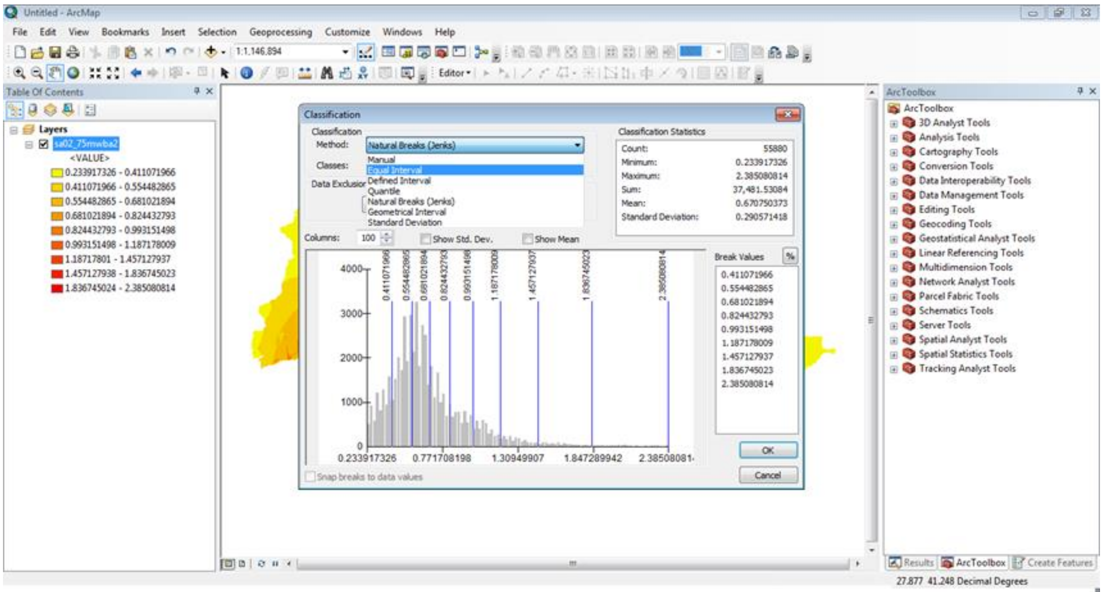

Figure 4.1: Choosing classification method

Break values could be manually imported to specify the breaking points of histogram.

4.2.1.1 Standard classification schemes

- Natural breaks (Jenks)

Classes are based on natural groupings of data values. ArcMap identifies break points by looking for groupings and patterns inherent in the data. The features are divided into classes as in Figure 4.2 whose boundaries are set where there are relatively big jumps in the data values (Minami et al., 1999).

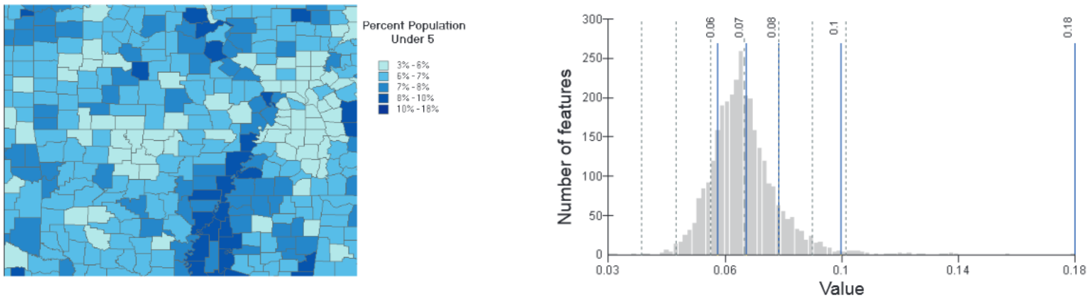

Figure 4.2: Natural Breaks Classification (Minami et al., 1999)

- Quantile

As shown in Figure 4.3**,** Each class contains an equal number of features. A quantile classification is well suited to linearly distributed data. Because features are grouped by the number in each class, the resulting map can be misleading. Similar features can be placed in adjacent classes, or features with widely different values can be put in the same class. This distortion could be minimized by increasing the number of classes (Minami et al., 1999).

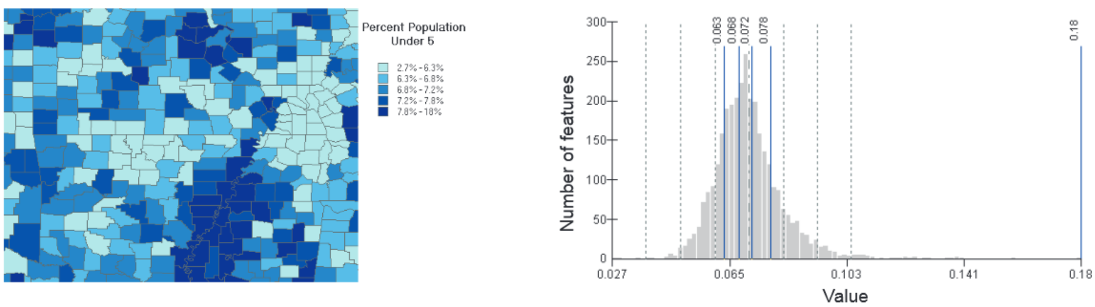

Figure 4.3: Quantile Classification (Minami et al., 1999)

- Equal interval

This classification scheme divides the range of attribute values into equal-sized subranges as in Figure 4.4. This method emphasizes the amount of an attribute value relative to other values (Minami et al., 1999).

This method emphasizes the amount of an attribute value relative to other values. For example, it will show that a store is part of the group of stores that make up the top one-third of all sales (Esri, 2014).

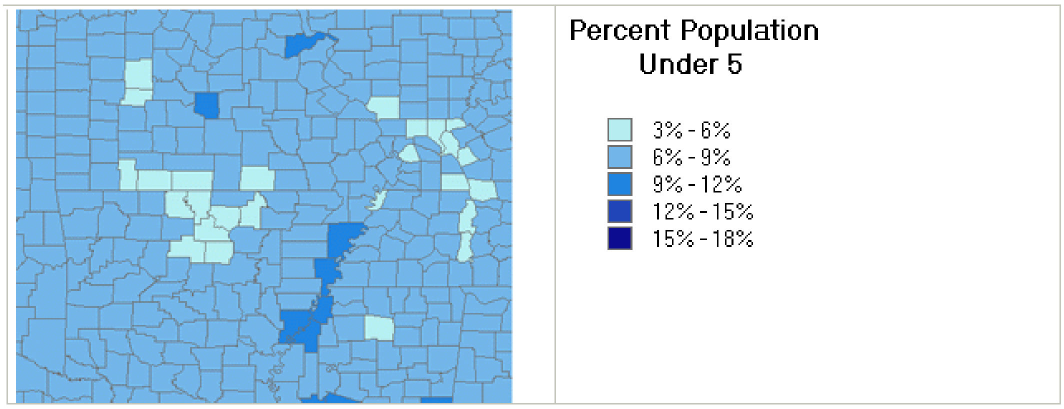

Figure 4.4: Equal Interval Classification (Esri, 2014)

To set up an equal interval classification, set the classification method to Equal Interval and specify the number of classes as in Figure 4.5 the number of classes is six (Esri, 2014).

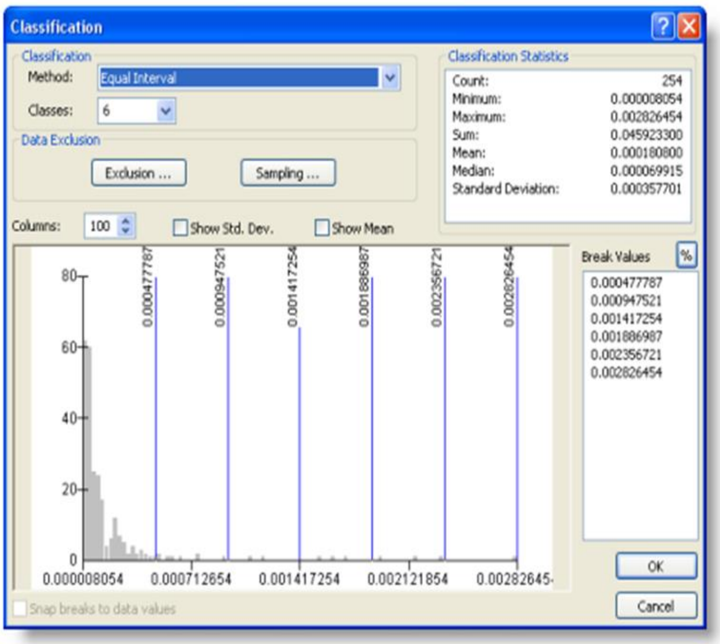

Figure 4.5: Equal Interval Method (Esri, 2014)

- Standard deviation

This classification scheme shows the amount a features attribute value varies from the mean. ArcMap calculates the mean value and then generates class breaks by successively adding to it or subtracting from it the standard deviation. A two-color ramp helps emphasize values above as in Figure 4.6 (shown in blue) and below (shown in red) the mean (Minami et al., 1999).

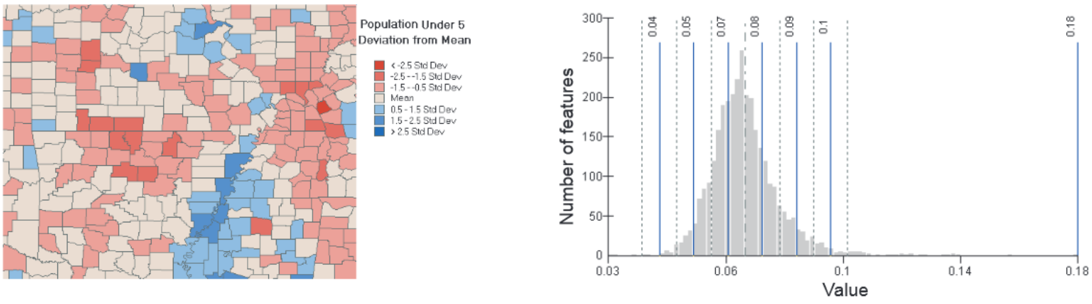

Figure 4.6: Standard Deviation Classification (Minami et al., 1999)

4.2.1.2 Manual classification

To classify the classes manually, Class breaks could be added like Figure 4.7 and it is possible to set the class ranges that are appropriate for data. Alternatively, it could start with one of the standard classifications and make adjustments as needed (Esri, 2013).

There may already be certain standards or guidelines for mapping the data. For example, temperature maps are often displayed with 10-degree temperature bands, or possibly emphasize features with particular values, for example, those above or below a threshold value (Esri, 2013).

Set the classification method to Manual, then click to set breaks and move class breaks (Esri, 2013).

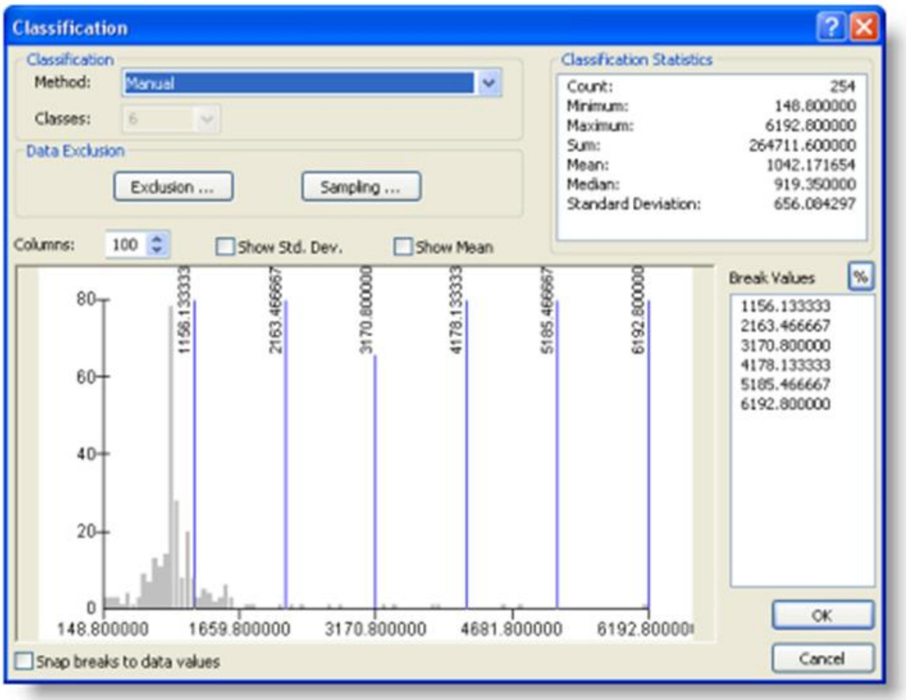

Figure 4.7: Manual Classification Method (Esri, 2013)

Class break values could be manually highlighted and updated in the graph or enter values in the right-hand Break Values box (Esri, 2013).

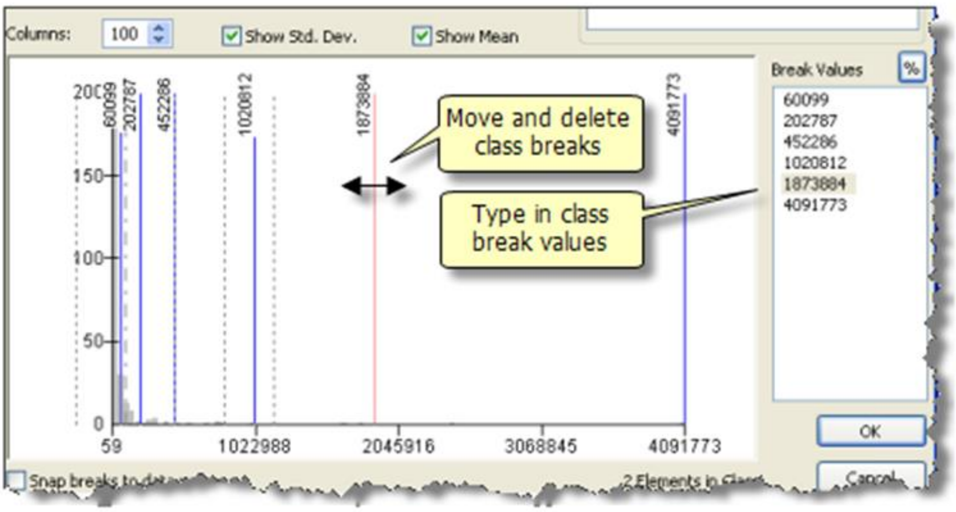

Figure 4.8: Changing the Break Values (Esri, 2013)

In the right-hand panel in Figure 4.8, Percent button % in Figure 4.9 makes it possible to work with the percentage of observations that fall in each class.

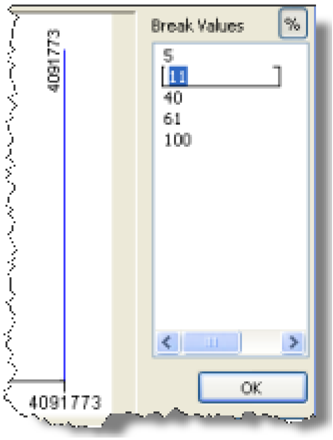

Figure 4.9: Percent Button (Esri, 2013)

4.2.2 Weighted sum

The Weighted Sum tool overlays several rasters, multiplying each by their given weight and summing them together and it is a useful way to add several rasters together is to input multiple rasters and set all weights equal to 1. The weight values can be any positive or negative decimal value. It is not restricted to a relative percentage or equal to 1.0 (Esri, 2014).

The steps for running Weighted Sum tool are as follows:

- Add rasters.

Click the Input raster arrow and click an input raster, or browse to an input raster and click Add. The raster is added to the Weighted Sum table. Repeat to enter the next raster, and so on.

- Select the field.

For each input raster, click the field column to specify the field to be used in the overlay analysis. A drop-down list -appears displaying all valid fields for the input. The field must be a numeric field.

- Assign weights for input raster.

Each input raster can be weighted, or assigned a percentage influence, based on its importance. For each input raster, click in the weight column to specify a value, the weights can be any floating-point value (negatives included).

- Run the tool.

In Figure 4.10**,** it is shown that the cell values of each input raster are multiplied by the raster's weight. The resulting cell values are added to produce the final output raster (Esri, 2014).

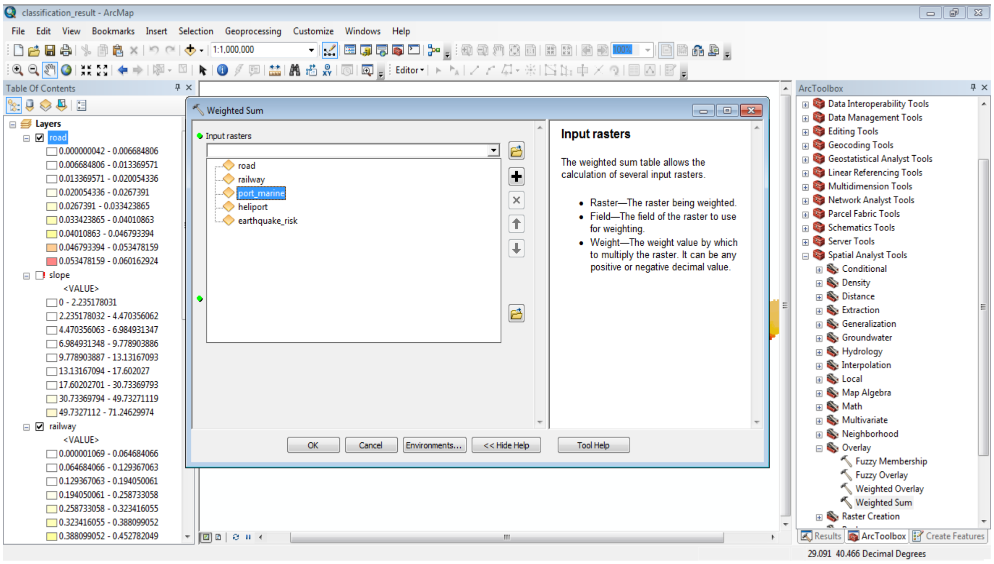

Figure 4.10: Weighted Sum Tool

4.2.2.1 Usage

- A useful way to add several rasters together is to input multiple rasters and set all weights equal to 1.
- Input raster can be integer or floating point.
- The weight values can be any positive or negative decimal value. It is not restricted to a relative percentage or equal to 1.0.
- The weight will be applied to the specified field for the input raster. Fields can be of type short or long integer, double or float.
- By default, this tool will take advantage of multi-core processors. The maximum number of cores that can be utilized is limited to four (Esri, 2014).

4.2.3 Model-Builder

ModelBuilder is an application could be used to create, edit, and manage models. Models are workflows that string together sequences of geoprocessing tools, feeding the output of one tool into another tool as input. ModelBuilder can also be thought of as a visual programming language for building workflows (Esri, 2014).

While ModelBuilder is very useful for constructing and executing simple workflows, it also provides advanced methods for extending ArcGIS functionality by allowing creating and sharing models as tool (Esri, 2014).

The benefits of ModelBuilder can be summarized as follows:

- ModelBuilder is an easy-to-use application for creating and running workflows containing a sequence of tools.
- You can create your own tools with ModelBuilder. Tools you create with ModelBuilder can be used in Python scripting and other models.
- ModelBuilder, along with scripting, is a way for you to integrate ArcGIS with other applications.
- ModelBuilder is how models and model tools are created. A model is nothing more than a sequence of tools and data chained together; the output of one tool is fed to the input of another. When a model is saved, it becomes a model tool (Esri, 2014).

As in Figure Figure 4.11, by opening ModelBuilder and clicking Geoprocessing > ModelBuilder , data and tools could be added to the ModelBuilder canvas by dragging them from the Catalog or Search window or by using the Add button . There are a variety of ways to connect data to tools; a common method is to use the Add Connection tool .

Once data is connected to tools, the model can be executed from within ModelBuilder by clicking the Run button (Esri, 2014).

4.2.3.1 The ModelBuilder interface

ModelBuilder has a simple interface with drop-down menus, tools on a toolbar, and shortcut menu options as illustrated below. Shortcut menus are available for the whole model or any individual model element (variable, connector, or tool) with a right-click. The white empty space in a model onto which the tools are dragged and connected to the variables is called the canvas, whereas the appearance and layout of the tools and variables connected together is called the model diagram (Esri, 2014).

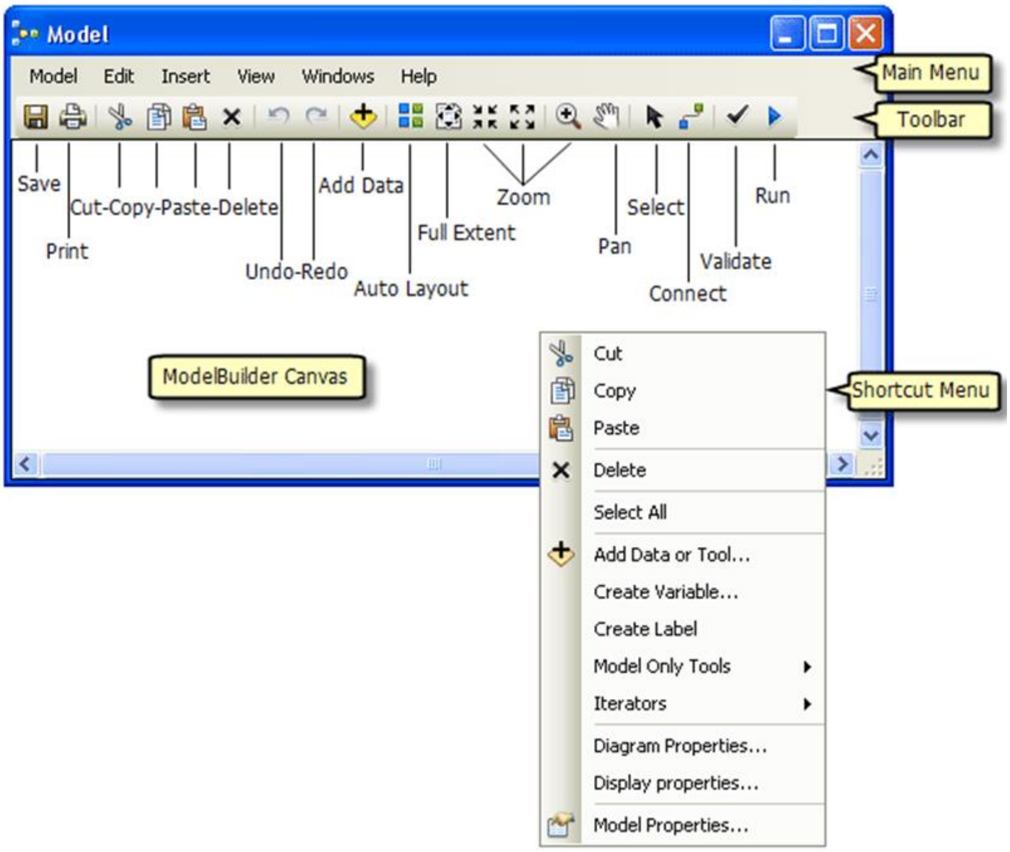

Figure 4.11: Model Builder Interface (Esri, 2014)

4.2.4 Raster Comparison

In ArcGIS, Raster Compare toolbox is used to compare the properties of two raster datasets, two raster catalogues, or two mosaic dataset and then returns the comparison result (Esri, 2013).

The following sections are the usage of this toolbox:

- The tool returns messages showing the comparison result.
- The parameter and attribute tolerances allow your comparisons to have a specified amount of leeway.

The following sections go through the process of raster compare:

1. From Arc toolbox→ Data management tools→ data comparison→ Raster compare

2. In the opened window as Figure 4.12, in input base raster, the base raster, and in input raster test raster, raster that is going to be compared should be selected.in ignore options the properties that you do not want to include in the comparison. To

determine the full list of properties, open the tool dialog and view the list of values for the Ignore Options parameter. Your Compare Type will determine which Ignore Options are valid.

3. By clicking ok comparison will be done and the results will be shown as a note file in document (Esri, 2013).

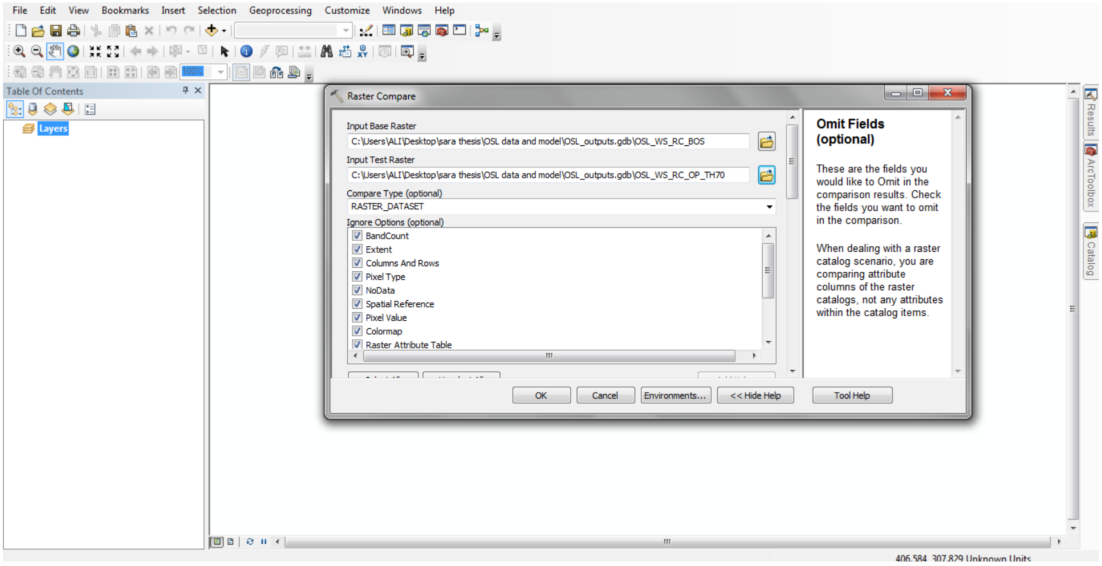

Figure 4.12: Raster Compare Tool

5. ANALYTICAL HIERARCHY PROCESS (AHP)

The Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions due to (Thomas L Saaty, 2000) and is often referred to, eponymously, as the Saaty method. It is popular and widely used, especially in military analysis, though it is not, by any stretch of the imagination, restricted to military problems. In fact, Saaty describes case applications ranging from the choice of a school for his son, through to the planning of transportation systems for the Sudan. There is much more to the AHP than we have space for but we will cover the most easily used aspects of it (Coyle R G - 1989) is an effective tool for dealing with complex decision making, and may aid the decision maker to set priorities and make the best decision. AHP helps to capture both subjective and objective aspects of a decision by reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results, the. Also, the AHP is a useful technique for checking the consistency of the decision maker's valuations, thus reducing the bias in the decision making process (Thomas L Saaty, 1977).

5.1 The Analytic Hierarchy Process

To make a decision in an organized way to generate priorities, it is needed to decompose the decision into the following steps.

- Define the problem and determine the kind of knowledge sought.
- Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives).
- Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.

- Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority.

Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level is obtained (TRF., 2008).

5.2 The Basic Principles of the AHP

The mathematics of the AHP and the calculation techniques are briefly explained in Annex A but its essence is to construct a matrix expressing the relative values of a set of attributes. For example, what is the relative importance to the management of this firm of the cost of equipment as opposed to its ease of operation? They are asked to choose whether cost is very much more important, rather more important, and important, and so on down to very much less important, than operability. Each of these judgments is assigned a number on a scale (TRF., 2008). An explanation of the importance scales can be seen in Table 5.1.

Table 5.1: The fundamental scale of absolute numbers (TRF., 2008)

Intensity of Importance	Definition
1	Equal Importance
2	Weak or slight
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance

The heart of his method, the Analytic Hierarchy Process, consists of the construction of pairwise comparison matrices and the extraction of weights by means of the principal right eigenvector. With a pairwise comparison matrix for n items the decision maker indicates how much more important (or how much more suitable, or how much better qualified, or whatever the basic comparison mode is) item i is then item j. The decision maker is explicitly required to make more pairwise comparisons then absolutely necessary (Dijkstra, 2011).

5.3 Implementation of the AHP

The AHP can be implemented in three simple consecutive steps:

1) Computing the vector of criteria weights.

2) Computing the matrix of option scores.

3) Ranking the options.

In this study, it is assumed that m evaluation criteria are considered, and n options are to be evaluated an useful technique for checking the reliability of the results (Thomas Lorie Saaty, 1996).

5.3.1 Computing the vector of criteria weights

The AHP can be implemented in three simple consecutive steps:

1) Computing the vector of criteria weight.

2) Computing the matrix of option scores.

3) Ranking the options (Thomas L Saaty, 2008)

Consider n elements to be compared, C1…Cn and denote the relative weight (or priority or significance) of Ci with respect to Cj by aij and form square matrix A=(aij) of order n with the constrains that aij=1/aji for i $\neq$ j , and aii=1 , all i. such a matrix is said to be a reciprocal matrix. The weights are consistent if they are transitive , that is aik=aij.ajk for all i, j and k. such a matrix might exist if the aij are calculated from exactly measured data. Then find a vector w of order n such that Aw=λw, for such a matrix w is said to be an eigenvalue. For a consistent matrix λ=n. for matrices involving of human judgment, the condition aik=aij.ajk does not hold as human judgments are inconsistent to a greater or lesser degree. In such a case the w vector satisfies the equation Aw= λmax w and λmax$\geq$n. the difference, if any, between λmax and n is an indication of the inconsistency of the judgments. If λmax =n then judgments have turned out to be consistent. Finally a consistency index (CI) can be calculated from:

$$CI=(\lambda max-n)/(n-1)$$

It needs to be assessed against judgments made completely at random and (Thomas L Saaty, 2008) has calculated large samples of random matrices of increasing order and the Consistency Indices of those matrices. By dividing the Consistency Index for the set of judgments by the Index for the corresponding random matrix a true consistency raio is calculated (International Hellenic University., 2012). The ındex parameters can be found in Table 5.2.

$$CR=CI/RI$$

Table 5.2: Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

5.3.2 Identification of used Criteria:

In the difficult situation experienced after the disaster, especially in terms of those who have to stay separate from the house and exposed to disasters is very important. These parts are the people who need to get rid of its influence to return to normal life and profoundly felt the destructiveness of disasters. Therefore, these people, their housing conditions in temporary settlements, at least until normalization and should be able to continue their lives in optimum conditions in these areas (K. H. Erden T, 2012).

In post-disaster conditions and the services, they provide temporary shelter areas can play a major role. The use of this space depending on the size of the disaster may take longer than expected. In addition, not only in disasters, social events, this may require the establishment of such areas.

Temporary shelter areas to be the only shelter that provides services for people beyond their field of health and safety, are systems that to some extent be able to live in safety and peace. Besides these areas, housing mania, health care and many times these may be granted education services.

All of the positions of these requirements necessitates the temporary shelter areas identified correctly. Otherwise, designed to lighten people’s lives and to facilitate the difficult conditions of these facilities can have unintended effects and may lead to results contrary to the forecast.

A study was carried out by the parallel nature of the UN High Commissioner for Refugees and the standards and conditions of living in the most efficient way to provide optimum conditions for asylum, which have been identified.

The World Health Organization (WHO) has also done some research on how plants could be of health conditions in these areas and has developed considerably in this direction.

UN-funded Checklist-Based Guide to Identifying Critical Environmental Considerations in Emergency Shelter Site Selection, Construction, Management and Decommissioning The environmental conditions of the GBA study evaluated and should be considered in the establishment of this field is determined by what the environmental standards.

In the first stage highlights and Red Crescent, ACUTE, IBB, etc. as a result of interviews with experts working in the agency experts who highlighted the criteria are listed below.

- Possibility to placement water tanks in the corresponding position
- Input (office management);
- Food distribution (material storage area and Parking-5 trucks + 5 cars);
- Medical clinics;
- Landfill and toilets-showers (50m far)
- Proximity to the road

In order to avoid panic be away from fault lines

Away from the sea

- According to the risk of flooding and tsunami, near the water,

Away from legal facility

- Chemical-producing plants,
- Substance use and inventories facilities
- Explosive substances stores
- Filling stations

- LPG stations
- Manure storages

All the criteria used to determine the shelter in the world literature were obtained in the following step was investigated and classified. These criteria are presented in Table 5.3.

Table 5.3: Used criteria in Determination of Housing Area in the Literature

Criterion	***Weights***		***Reference***
Accessibility	0.1983	(Chao, 2012)	(Tong vd., 2012), (Cheng ve Yang, 2012), (Chu ve Su, 2011), (Wishner ve Adams, 2002), (UNHCR, 2007), (SCHR, 2004)
Capacity	0.3415	(Chao, 2012)	(Tong vd., 2012), (Cheng ve Yang, 2012), (Chu ve Su, 2011), (Wishner ve Adams, 2002), (UNHCR, 2007), (SCHR, 2004)
Topography	0.0584	(Chao, 2012)	(Tong vd., 2012), (Cheng ve Yang, 2012), (Chu ve Su, 2011), (Wishner ve Adams, 2002), (UNHCR, 2007), (SCHR, 2004)
Land Usage	0.0428	(Chao, 2012)	(Tong vd., 2012), (Cheng ve Yang, 2012), (Chu ve Su, 2011), (Wishner ve Adams, 2002), (UNHCR, 2007), (SCHR, 2004)
Infrastructure	0.1627	(Chao, 2012)	(Tong vd., 2012), (Cheng ve Yang, 2012), (Chu ve Su, 2011), (Wishner ve Adams, 2002), (UNHCR, 2007), (SCHR, 2004)
Physical Damage Vulnerability	0.0489	(SCHR, 2004), (Kelly, 2005)	(Tong vd., 2012), (Cheng ve Yang, 2012), (Chu ve Su, 2011), (Wishner ve Adams, 2002), (UNHCR, 2007)
Contact	0.0432	(SCHR, 2004), (Kelly, 2005)	(Tong vd., 2012), (Cheng ve Yang, 2012), (Chu ve Su, 2011), (Wishner ve Adams, 2002), (UNHCR, 2007)
Land Type	0.0318	(SCHR, 2004), (Kelly, 2005)	
Morphology	0.0235	(2007)	
Meteorology	0.0489	(2007)	

In this context, the weights obtained were determined and compared with international standards and with standards. It is suggested to consider weighting process in two stages. Thus initially divided into two groups upper and lower sub-groups of each group that is shaped to form an upper top group (Table 5.3).

Table 5.4 Provided the list of contributions is provided for the detection of temporary housing after the disaster.

Table 5.4: List of institutions and organizations that provided Questionnaires

Institution Name	Class
Istanbul Technical University: Civil, Geomatics, Geology Engineering Departments	University
Bogazici University: Kandilli Observatory, Economy Department	University
Middle East Technical University: Sociology Department	University
TU Wien	University
University of Tabriz	University
DASK (Natural Hazards Insurance Agency)	Public Enterprise
Turkish Red Crescent	Public Organization
Istanbul AFAD	Public Institution
Istanbul Metropolitan Municipality	Local Authority
AKUT (Search & Rescue Association)	NGO
MAG (Neighbourhood Disaster Volunteers)	NGO
GEA (Search & Rescue Group) INSARAG Member	NGO

In this context, the main criteria and sub-criteria determined by the expert opinion.

5.4 Questionnaires for Criteria

Some questionnaires according to pairwise comparison provided about main criteria and asked from the academics of Geomatics department, Earthquake engineering and disaster management department, and some of students of civil engineering (Table 5.5).

Table 5.5: Questionnaires about critesias using pairwise comparison (Karaman, H., 2014)

criterias	*Pairwise Comparison*																	*Criteria*
	Very very strong	Between very and very very strong	Very strong	Between strong and very strong	strong	Moderate and strong	moderate	Equal and moderate	Equal	Equal and moderate	moderate	Moderate and strong	strong	Between strong and very strong	Very strong	Between very and very very strong	Very very strong	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Infrustructure (AL)																		*ER*
																		HG
																		TO
																		KA
																		AK
Accessibility (ER)																		*HG*
																		TO
																		KA
																		AK
Hazard (TH)																		*TO*
																		KA
																		AK
Topography (TO)																		*KA*
																		AK
Capacity (KA)																		*AK*
Name,Surename																		
Title																		
Profession																		

5.5 Questionnaires for Sub Criteria:

Each criterion divided to its sub-criteria; and for each criterion, a questionnaire provided and sent to the institutions to obtain the weights of each criteria by using analytical hierarchy process in order to understand the importance of each sub criteria (Karaman, H., 2014).

Subgroups of Infrastructure criteria (Table 5.6): İL: Communication infrastructure, SU: Drinking water infrastructure, KN: Waste Water infrastructure, EL: Electric infrastructure, GZ: Gas infrastructure

Table 5.6: Questionnaire for sub criteria of infrustructure (Karaman, H., 2014)

Criteria	*Pairwise Comparison Criterias*																	*Criteria*
	Very very strong	Between very and very very strong	Very strong	Between strong and very strong	strong	Moderate and strong	moderate	Equal and moderate	Equal	Equal and moderate	moderate	Moderate and strong	strong	Between strong and very strong	Very strong	Between very and very very strong	Very very strong	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
communication (İL)																		*SU*
																		KN
																		EL
																		GZ
Drinking water (SU)																		*KN*
																		EL
																		GZ
Sewerage (KN)																		*EL*
																		GZ
Electricity (EL)																		*GZ*
Name,surename																		
Tizle																		
Profession																		

Hazard (Table 5.7) to: DP: Earthquake hazard, TS: Tsunami hazard, HY: Landslide hazard, SB: Flooding hazard, KM: Chemical Leak hazard, YN: Fire hazard

Table 5.7: Questionnaire for sub criteria of Hazard (Karaman, H., 2014)

Criterias	*Pairwise Comparison Criteria*																	*Criteria*
	Very very strong	Between very and very very strong	Very strong	Between strong and very strong	strong	Moderate and strong	moderate	Equal and moderate	Equal	Equal and moderate	moderate	Moderate and strong	strong	Between strong and very strong	Very strong	Between very and very very strong	Very very strong	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Earthquake (DP)																		*TS*
																		HY
																		SB
																		KM
																		YN
Tsunami (TS)																		*HY*
																		SB
																		KM
																		YN
Landslide(HY)																		*SB*
																		KM
																		YN
Flooding(SB)																		*KM*
																		YN
Chemical (KM)																		*YN*
Name,surename																		
Title																		
Profession																		

Accessibility (Table 5.8) to: KR: Highways, DM: Railways, HV: Heliport, DN: Marine ports

Table 5.8: Questionnaire for sub criteria of Accessibility (Karaman, H., 2014)

Criterias	*Pairwise Comparison Criterias*																	*Criteria*
	Very very strong	Between very and very very strong	Very strong	Between strong and very strong	strong	Moderate and strong	moderate	Equal and moderate	Equal	Equal and moderate	moderate	Moderate and strong	strong	Between strong and very strong	Very strong	Between very and very very strong	Very very strong	
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Highways (KR)																		*DN*
																		HV
																		DM
Sea routes (DN)																		*HV*
																		DM
Helicopter (HV)																		*DM*
Name,surename																		
Title																		
Profession																		

The weights were calculated step by step using the questionnaires which were collected in the forms. All the answers were document into an excel file and the calculation were applied to them according to AHP (Karaman, H., 2014).

And results are shown in tables below:

Table 5.9: Main Criteria Weights (Karaman, H., 2014)

Criterion	***Weight***
Infrastructure (AL)	0.173060185
Accessibility (ER)	0.207038856
Hazard (TH)	0.312750816
Topography (TO)	0.095361821
Capacity (KA)	0.155191613
Land Usage (AK)	0.056596709
Total	**1.000**

Table 5.10: Infrastructure sub-criteria weights (Karaman, H., 2014)

Criterion	*Weight*
Communication (İL)	0.062744009
Drinking Water Lines (SU)	0.233614496
Waste Water Lines (KN)	0.488718001
Electric Lines (EL)	0.152171658
Gas Lines (GZ)	0.062751836
Total	**1.000**

Table 5.11: Hazard Sub-criteria weights (Karaman, H., 2014)

Criterion	*Weight*
Earthquake (DP)	0.074002659
Tsunami (TS)	0.074003731
Landslide (HY)	0.131638371
Flooding (SB)	0.131638371
Chemical Leak (KM)	0.227223997
Fire (YN)	0.361492871
Total	**1.000**

Table 5.12: Accessibility Sub-criteria weights (Karaman, H., 2014)

Criterion	*Weight*
Roads - Highways (KR)	0.542328824
Marin-ports (DN)	0.084672479
Heli-port Stations (HV)	0.139696571
Railways (DM)	0.233302126
Total	**1.000**

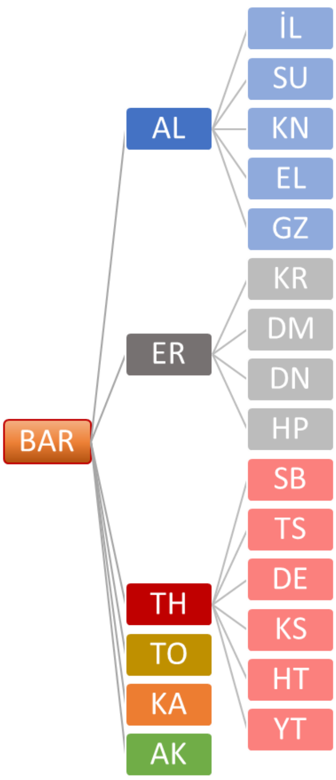

Figure 5.1 : Criteria and Sub-criteria Weights and relationships (Karaman, H., 2014)

6. SENSITIVITY ANALYSIS

Sensitivity Analysis (SA) is the study of how the uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input. The SA is hence considered by some as a prerequisite for model building in any setting, be it diagnostic or prognostic, and in any field where models are used (Saltelli, A., Chan, K. & Scott, 2000).

In addition, sensitivity analysis is a prerequisite for model building since it determines the reliability of the model through assessment of uncertainties in the simulation results. With growing interest in extending GIS to support multi-criteria decision-making (MCDM) methods, enhancing GIS-based MCDM with sensitivity analysis procedures is crucial. SA should be involved in GIS-MCDM model evaluation that tests the robustness of a model and the extent of output variation when parameters are systematically varied over a range of interest. The most common approach is based on varying criteria or their weights, which represents input parameters in order to understand the model behavior and its limitations (Chen, Khan, & Paydar, 2010).

The integration of SA with AHP using GIS has enhanced the conventional AHP module, improved the reliability of MCDM output, and extended existing GIS functionalities. This GIS based AHP-SA tool supplies more immediate feedback to evaluators/modelers. It is easier for non-experts to understand, and provides a mechanism to explore the decision problem while learning how changes in criteria weights affect evaluation outcomes spatially and quantitatively. It enables decision makers to follow/conduct a comprehensive yet easy-to-use procedure to examine weight sensitivity in both criteria and geographic space (Chen et al., 2010).

For a wide class of multi attribute decision models (Wolters & Mareschal, 1995) showed how to determine the stability intervals or regions for the weights of different criteria. These consist of the values that the weights of one or more criteria can take without altering the results given by the initial set of weights, all other weights being kept constant. (Wolters & Mareschal, 1995) proposed a linear programming model to find the minimum modification of the weights required to make a certain alternative ranked first.

(Triantaphyllou & Sánchez, 1997) presented an approach of a more complex sensitivity analysis with the change of the scores of the alternatives against the criteria, as well (Triantaphyllou & Sánchez, 1997).

They have conducted a sensitivity analysis of GIS-based analysis on how to apply the MCDM problems. The review in the evaluation of the final product shows that very little attention. The sensitivity analysis has not been a general practice issue in GIS-based MCDM application. Sensitivity analysis for MCDM applications still need to be filled and is seen as a nascent field. Criteria to determine the effect on the change in weight results from the model is the most commonly used sensitivity analysis. GIS-based MCDM application of weight sensitivity to the critical lack of criteria for the implementation of the method stems from lack of sensitivity analysis in addition to the spatial component (Delgado, M. G. & Sendra, 2004).

MCDM problems in GIS-based sensitivity analysis applications, making use of GIS spatial analysis and visualization possibilities, the criteria to visualize the spatial sensitivity of weight and weight change allows testing with spatial analysis (Feick & Hall, 2004).

The purpose of sensitivity analysis is stated as follows: “the implementation of the model sensitivity analysis and decision-making appears to be a fundamental concept used in an effective manner. The purpose of sensitivity analysis is to evaluate the stability and consistency of the parameters change under the most appropriate solution. “Following the change to an extent that is exposed to small weight changes in the sensitivity analysis for any criteria specified critical values. The following equation was used for sensitivity analysis will be applied to the relevant criteria (Opricovic & Tzeng, 2004):

$$w_j = (1 - w_i) \times (\frac{w_j^*}{1 - w_i^*})$$

- w_j , shows the j parameter new weight value to be used in the sensitivity analysis.
- w_i, i subjected to decrease or increase weight in the sensitivity analysis, Extent the new weight value.

- w^*_i and w^*_j are the previous weight values of criteria without being subjected to sensitivity analysis.

A multi-discipline practices are used in applications where sensitivity analysis is summarized as follows in their respective fields.

7. IMPLEMENTATION OF THE THESIS

In this study, sensitivity analysis are structured on Istanbul metropolitan optimum shelter locations map that is created by using Analytic Hierarchy Method and GIS, also sensitivity analysis is applied on Istanbul hazards map, accessibility map and infrastructure map to provide support of sensitivity created model for decision makers who carried out the model.

Sensitivity analysis are structured by advantages of GIS visualization and spatial facilities. Criteria weights predetermined based on expert opinions, criteria weights are subjected to spatial analysis and maps were created.

Spatial Analyst extension of Arcmap 10.1 platform in ArcGIS Software and ArcToolbox extension are used to Analysis.

The criteria used in the analysis AL (Altyapı – Infrastructure), ER (Erisebilirlik – Accessbility), TH (Tehlike – Hazard), TO (Topografya – Topography), KA (Kapasite – Capacity), AK (Arazi Kullanımı – Land Use), depicted by different layer in ArcGIS software. Each criterion is converted to raster data format. In order to analysis raster criteria reclassify process is applied for each criteria.

After these processes by using weighted sum tool in spatial analyst toolbox in ArcToolbox overlay analysis was performed.

For each criterion, raster data was taken as the basic input, based on Analytic Hierarchy Process, weights produced for criteria are subjected to weighted addition.

After the model created in ArcGIS model builder platform in Figure 7.1**,** sensitivity analysis criteria are redefined according to specific intervals determined by the advisor.

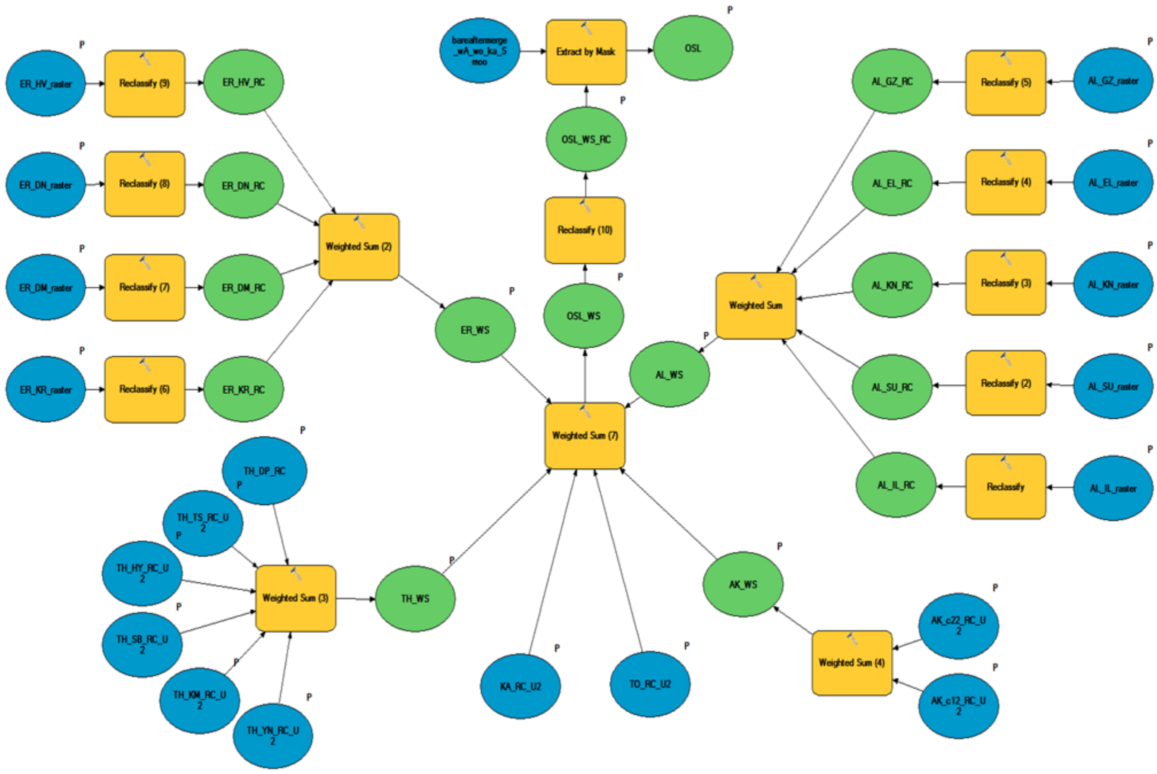

Figure 7.1: Optimum shelter location model (Karaman, H., 2014)

The following equation was used as sensitivity analysis application to the relevant criteria (Opricovic & Tzeng, 2004):

$$w_j = (1 - w_i) \times (\frac{w_j^*}{1 - w_i^*})$$

w_j , shows the j parameter new weight value to be used in the sensitivity analysis.

w_i, i subjected to decrease or increase weight in the sensitivity analysis. the extent of the new weight value.

w^*_i and w^*_j are the previous weight values of criteria without being subjected to sensitivity analysis.

According to the above formulation for AL (infrastructure) criteria by the weight value w_i = 0.3 (30%), TH (Hazard) criteria will have a new weight value:

$$(1 - 0.3) \times \left(\frac{0.313}{1 - 0.173}\right) = w_j = 0.265$$

In this study on the basis of each criteria (AL, ER, TH, TO, KA, AK), for all criteria the weight between 0% to 100% by the weight value 10%, and also on the basis of each Sub-Criteria (DP, TS, HY, SB, KM, YN ,IL, SU, KN, EL , GZ, KR, DN , HV, DM), for all other Sub-Criteria the weight between 0% to 100% by weight value 25% sensitivity analysis applied and results are shown in the appendix tables(Table A.1 to Table A.21).

For Sensitivity analysis over weight determined by AHP 60 sensitivity analysis for main criteria and 75 sensitivity analysis for Sub-Criteria was performed in GIS environment. In the analysis for each criterion when the weight value changes from 0% to 100%, all other criteria's values changes based on their determined weight value.

In Appendix (Figure A.1 to Figure A.145), all results of the sensitivity analysis in GIS environment are given visually. According to these maps, for example for TH criterion analysis calculated between (Figure A.46 to Figure A.56) shows evaluation based on weight variation. In the following an example can be seen that how the result map can be produced when the TH criterion value is 50%:

At first in the ArcGIS software, after openning the built model option from catalog box, and right-click on the optimum shelter location model, the Edit option is selected as it can be seen in Figure 7.2:

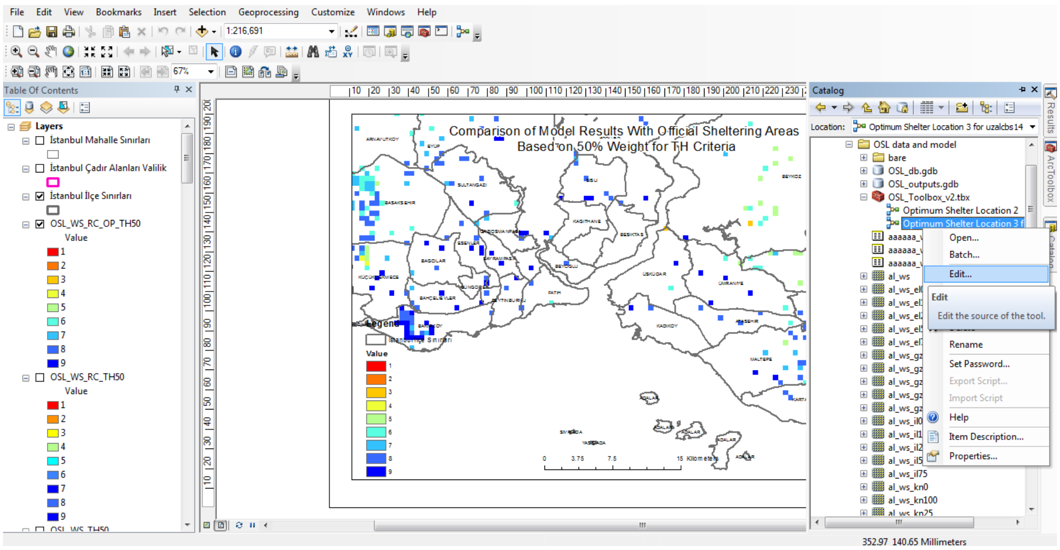

Figure 7.2: Optimum shelter Location Toolbox

After that it can be seen the optimum shelter location model that is provided for Istanbul city (Figure 7.3).

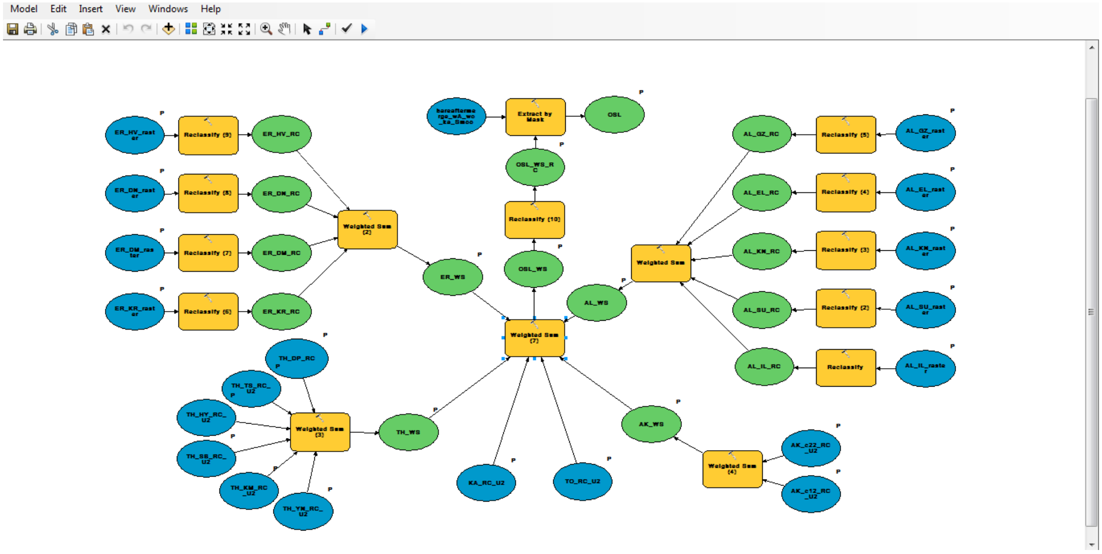

Figure 7.3: Optimum Shelter Location Model

Now the weighted sum box is selected and click on it, so the values of all criteria in the model are reached and the values of all criteria are changed that is calculated when the TH values is 50% as can be seen in Figure 7.4:

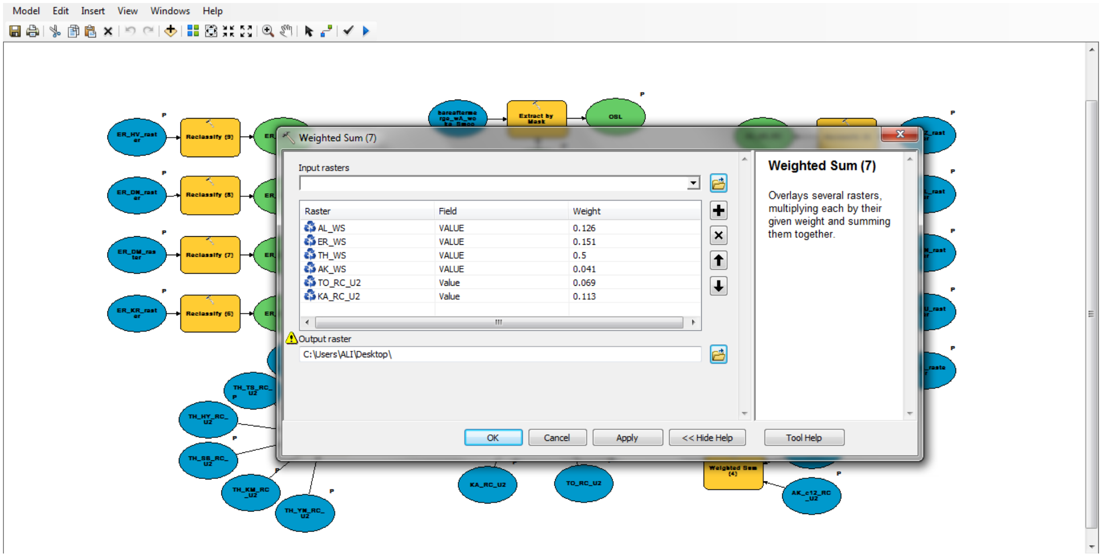

Figure 7.4: Weighted Sum Toolbox (Main Criteria)

Now after clicking on the weighted sum and select the Run, after a few minutes the classify is ran and also extract by mask to get the result, but before the last level the classification from the layer properties is done, as it is shown in Figure 7.5:

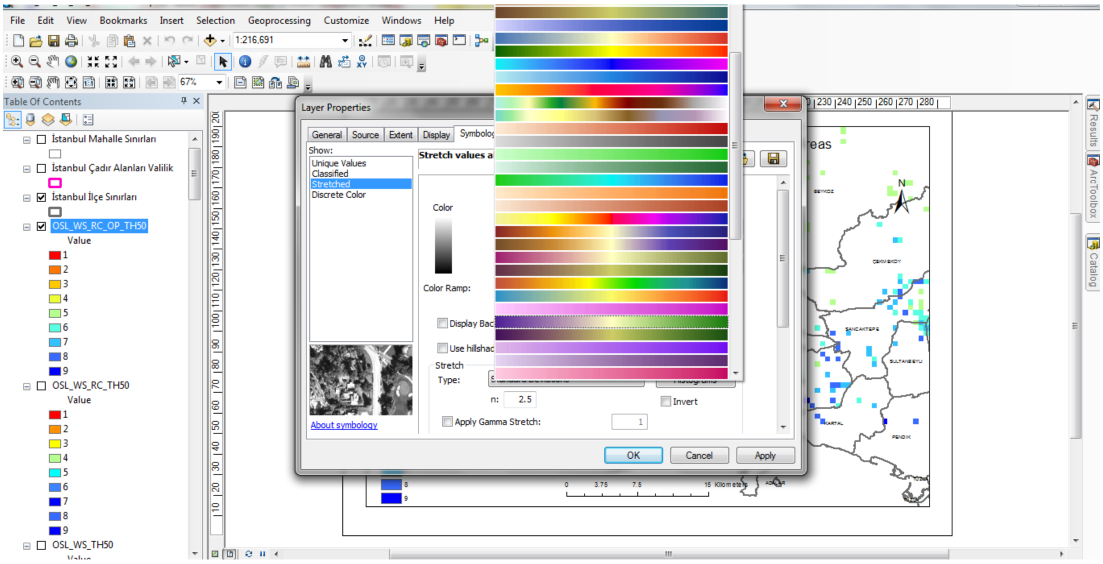

Figure 7.5: Classification Toolbox

After the classification, it can be seen optimum shelter locations map for Istanbul when the value of TH criterion is 50% as can be seen in Figure 7.6:

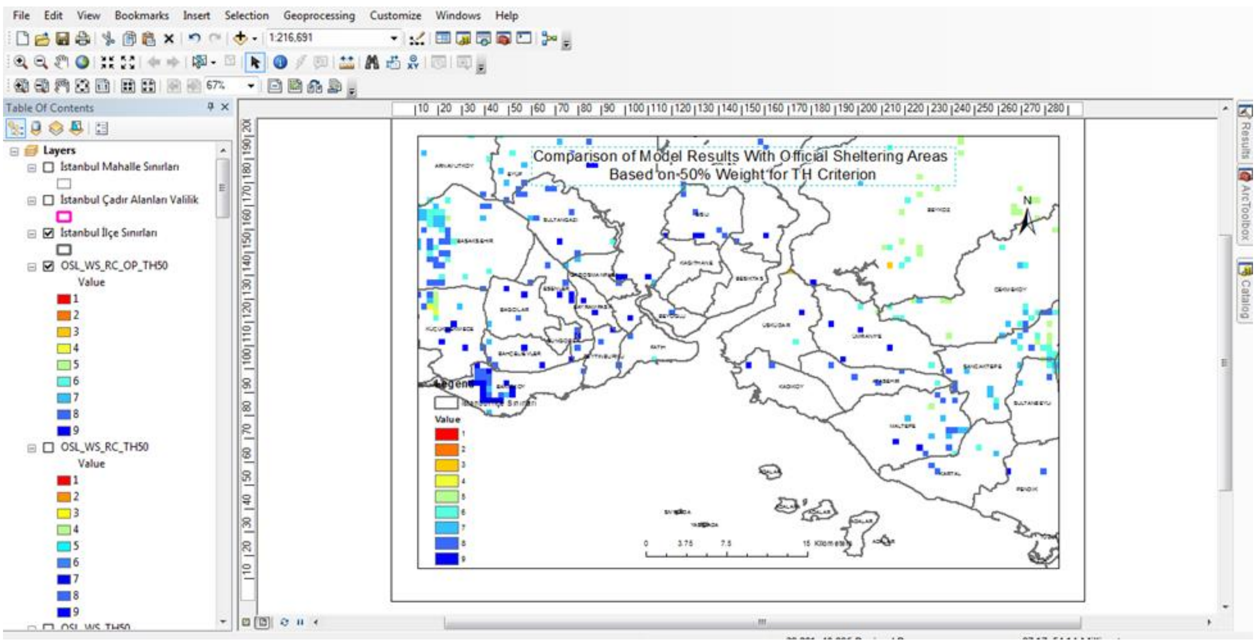

Figure 7.6: Result Map Based on 50% weight for TH Criterion

We use Raster Compare toolbox in ArcGIS software to attached the results of compare between raster inputs for each criterion (Table A.22 to Table A.33), after getting the visual results, for example the result of raster compare toolbox is ran for (TH) parameter when the weight is 30% is shown in Figure 7.7:

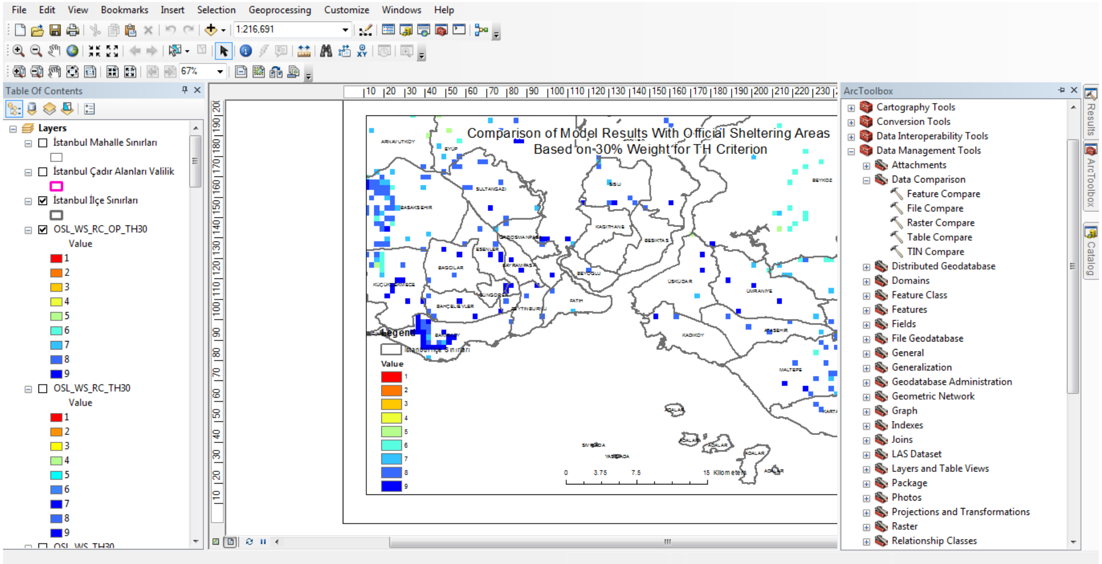

Figure 7.7: Data Comparison Toolbox

Therefore, the Raster Compare is selected and in the opened window, two raster files are inputted to compare, also the statistics is selected to see the means and standard deviations in the result text, as can be seen in Figure 7.8:

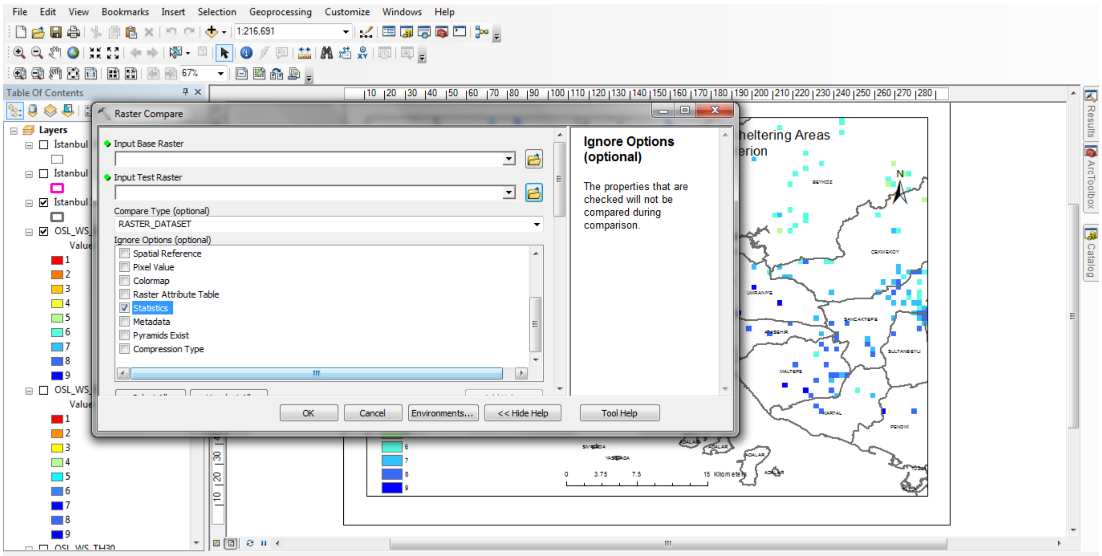

Figure 7.8: Raster Compare Toolbox

After running this analysis, the result as a text file can be seen in Figure 7.9:

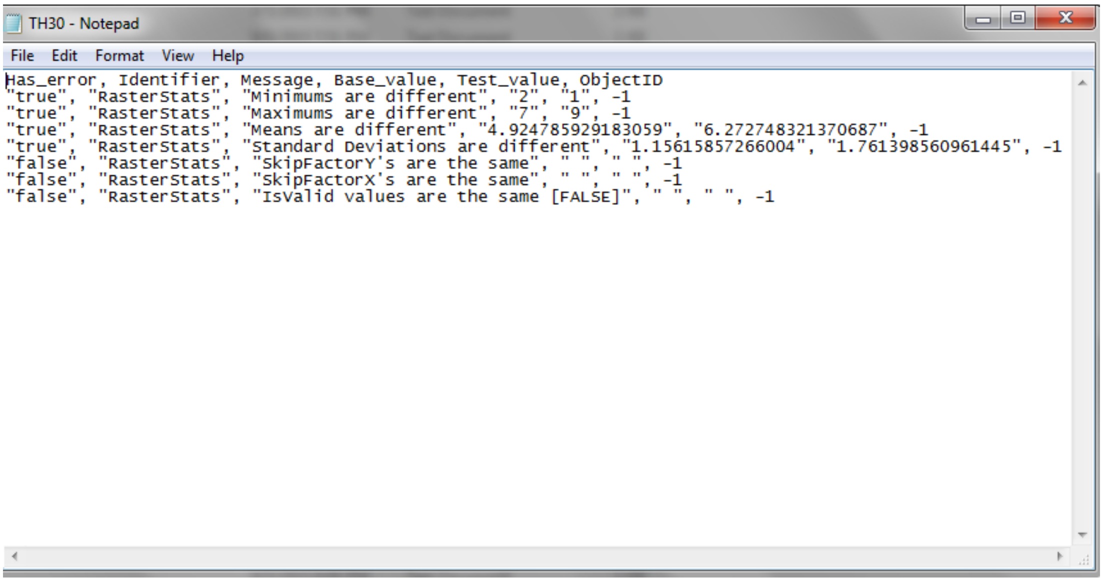

Figure 7.9: Statistics Result For TH Criterion Based on 30% Weight

According to the result tables when the Mean value increase, the standard deviation value should be controled to find in the which range of changes, the difference between fixed standard deviation and the variable is increasing, so just the weights that difference between fixed and variable values are less are acceptable, in this situation maybe it is reached some results those are not in our predicted range,as it is shown in the results table.

7.1 Sensitivity analysis results for the main criteria:

For Infrastructure (AL) criterion, based on given weight the following results were obtained; For AL parameter based on 17.3 wt. % in the model, sensitivity analysis were applied for 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is less than 10 wt.% and more than 40 wt.% for this criterion. So the sensitivity analysis results for Infrastructure (AL) parameter are acceptable between 10-40 wt.% and can be seen in Table 7.1.

Table 7.1: Means and Standard Deviations for AL Parameter

Infrastructure's (AL) Weight	Mean	Standard Deviation
0.173	4.925	1.156
0.000	5.085	1.909
0.100	5.736	1.816
0.200	6.327	1.738
0.300	6.909	1.713
0.400	7.384	1.676
0.500	7.472	1.748
0.600	7.851	1.632
0.700	7.794	1.686
0.800	6.181	1.843
0.900	7.758	1.792
1.000	7.681	1.855

For Accessibility (ER) criterion, based on given weight the following results were obtained; For ER parameter based on 20.7 wt. % in the model, sensitivity analysis were applied for 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is less than 20 wt.% and more than 70 wt.% for this criterion. So the sensitivity analysis results for Accessibility (ER) parameter are acceptable between 20-70 wt.% and can be seen in Table 7.2.

Table 7.2: Means and Standard Deviations for ER Parameter

Accessibility's (ER) Weight	Mean	Standard Deviation
0.207	4.925	1.156
0.000	4.849	2.127
0.100	5.497	1.945
0.200	6.132	1.765
0.300	6.727	1.617
0.400	7.268	1.530
0.500	7.705	1.403
0.600	7.993	1.315
0.700	8.070	1.285
0.800	8.129	1.313
0.900	7.758	1.792
1.000	7.681	1.855

For Hazard (TH) criterion, based on given weight the following results were obtained; For TH parameter based on 31.3 wt. % in the model, sensitivity analysis were applied for 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is less than 30 wt.% and more than 50 wt.% for this criterion. So the sensitivity analysis results for Hazard (TH) parameter are acceptable between 30-50 wt.% and can be seen in Table 7.3.

Table 7.3: Means and Standard Deviations for TH Parameter

Hazard's (TH) Weight	Mean	Standard Deviation
0.313	4.925	1.156
0.000	7.227	1.624
0.100	7.303	1.744
0.200	6.982	1.836
0.300	6.273	1.761
0.400	5.499	1.732
0.500	4.727	1.770
0.600	3.889	1.821
0.700	3.027	1.912
0.800	2.368	1.941
0.900	1.977	1.977
1.000	1.970	2.129

For Topography (TO) criterion, based on given weight the following results were obtained; For TO parameter based on 9.5 wt. % in the model, sensitivity analysis were applied for 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is less than 40 wt.% and more than 50 wt.% for this criterion. So the sensitivity analysis results for Topography (TO) parameter are acceptable between 40-50 wt.% and can be seen in Table 7.4.

Table 7.4: Means and Standard Deviations for TO Parameter

Topography's (TO) Weight	Mean	Standard Deviation
0.095	4.925	1.156
0.000	5.565	1.959
0.100	6.213	1.743
0.200	6.819	1.567
0.300	7.388	1.393
0.400	7.813	1.241
0.500	8.062	1.125
0.600	8.200	1.005
0.700	8.273	1.913
0.800	8.159	0.804
0.900	7.883	0.586
1.000	7.880	0.495

For Capacity (KA) criterion, based on given weight the following results were obtained; For KA parameter based on 15.5 wt. % in the model, sensitivity analysis were applied for 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 20 wt.% for this criterion. So the sensitivity analysis results for Capacity (KA) parameter are acceptable between 0-20 wt.% and can be seen in Table 7.5.

Table 7.5: Means and Standard Deviations for KA Parameter

Capacity's (KA) Weight	Mean	Standard Deviation
0.155	4.925	1.156
0.000	6.266	1.299
0.100	6.263	1.507
0.200	6.095	1.984
0.300	5.893	2.649
0.400	5.542	3.209
0.500	4.191	3.346
0.600	2.273	2.261
0.700	2.223	2.322
0.800	3.517	2.866
0.900	4.254	2.921
1.000	4.122	2.950

For Land Usage (AK) criterion, based on given weight the following results were obtained; For AK parameter based on 5.7 wt. % in the model, sensitivity analysis were applied for 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 50 wt.% for this criterion. So the sensitivity analysis results for Land Usage (AK) parameter are acceptable between 0-50 wt.% and can be seen in Table 7.6.

Table 7.6: Means and Standard Deviations for AK Parameter

Land Usage's (AK) Weight	Mean	Standard Deviation
0.057	4.925	1.156
0.000	6.784	1.753
0.100	5.695	1.735
0.200	4.513	1.692
0.300	3.337	1.559
0.400	2.210	1.267
0.500	1.430	0.994
0.600	1.254	0.844
0.700	1.404	0.999
0.800	1.748	1.303
0.900	1.707	1.206
1.000	1.553	1.130

7.2 Sensitivity analysis results for the sub-criteria:

For Communication (IL) sub-criterion of Infrastructure (AL) criterion, based on given weight the following results were obtained; For IL parameter based on 6.3 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 50 wt.% for this sub-criterion. So the sensitivity analysis results for Communication (IL) parameter are acceptable between 0-50 wt.%.

For Drinking Water Lines (SU) sub-criterion of Infrastructure (AL) criterion, based on given weight the following results were obtained; For SU parameter based on 23.3 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 50 wt.% for this sub-criterion. So the sensitivity analysis results for Drinking Water Lines (SU) parameter are acceptable between 0-50 wt.%.

For Waste Water Lines (KN) sub-criterion of Infrastructure (AL) criterion, based on given weight the following results were obtained; For KN parameter based on 48.9 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is less than 25 wt.% and more than 50 wt.% for this sub-criterion. So the sensitivity analysis results for Waste Water Lines (KN) parameter are acceptable between 25-50 wt.%.

For Electricity Lines (EL) sub-criterion of Infrastructure (AL) criterion, based on given weight the following results were obtained; For EL parameter based on 15.2 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 25 wt.% for this sub-criterion. So the sensitivity analysis results for Electricity Lines (EL) parameter are acceptable between 0-25 wt.%.

For Gas Stations (GZ) sub-criterion of Infrastructure (AL) criterion, based on given weight the following results were obtained; For GZ parameter based on 6.3 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 50 wt.% for this sub-criterion. So the sensitivity analysis results for Gas Stations (GZ) parameter are acceptable between 0-50 wt.%.

For Roads and Highways (KR) sub-criterion of Accessibility (ER) criterion, based on given weight the following results were obtained; For KR parameter based on 54 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is less than 25 wt.% and more than 75 wt.% for this sub-criterion. So the sensitivity analysis results for Roads and Highways (KR) parameter are acceptable between 25-75 wt.%.

For Marine-Ports (DN) sub-criterion of Accessibility (ER) criterion, based on given weight the following results were obtained; For DN parameter based on 8.5 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 75 wt.% for this sub-criterion. So the sensitivity analysis results for Marine-Ports (DN) parameter are acceptable between 0-75 wt.%.

For Heliport Stations (HV) sub-criterion of Accessibility (ER) criterion, based on given weight the following results were obtained; For HV parameter based on 14 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 50 wt.% for this sub-criterion. So the sensitivity analysis results for Heliport Stations (HV) parameter are acceptable between 0-50 wt.%.

For Railways (DM) sub-criterion of Accessibility (ER) criterion, based on given weight the following results were obtained; For DM parameter based on 23.3 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 75 wt.% for this sub-criterion. So the sensitivity analysis results for Railways (DM) parameter are acceptable between 0-75 wt.%.

For Earthquake Hazard (DP) sub-criterion of Hazard (TH) criterion, based on given weight the following results were obtained; For DP parameter based on 7.4 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 25 wt.% for this sub-criterion. So the sensitivity analysis results for Earthquake Hazard (DP) parameter are acceptable between 0-25 wt.% and can be seen Table 7.7.

Table 7.7: Means and Standard Deviations for DP Parameter

Earthquake Hazard's (DP) Weight	Mean	Standard Deviation
0.074	2.949	1.183
0.000	2.767	1.301
0.250	3.387	0.946
0.500	4.010	0.800
0.750	4.632	0.962
1.000	5.252	1.323

For Landslide Hazard (HY) sub-criterion of Hazard (TH) criterion, based on given weight the following results were obtained; For HY parameter based on 13.2 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 25 wt.% for this sub-criterion. So the sensitivity analysis results for Landslide Hazard (DP) parameter are acceptable between 0-25 wt.% and can be seen Table 7.8.

Table 7.8: Means and Standard Deviations for HY Parameter

Landslide Hazard's (HY) Weight	Mean	Standard Deviation
0.132	2.949	1.183
0.000	2.998	1.058
0.250	2.907	1.334
0.500	2.812	1.728
0.750	2.717	2.175
1.000	2.626	2.647

For Chemical Hazard (KM) sub-criterion of Hazard (TH) criterion, based on given weight the following results were obtained; For KM parameter based on 22.7 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 50 wt.% for this sub-criterion. So the sensitivity analysis results for Chemical Hazard (KM) parameter are acceptable between 0-50 wt.% and can be seen in Table 7.9.

Table 7.9: Means and Standard Deviations for KM Parameter

Chemical Hazard's (KM) Weight	Mean	Standard Deviation
0.227	2.949	1.183
0.000	3.020	0.968
0.250	2.945	1.216
0.500	2.866	1.640
0.750	2.790	2.138
1.000	2.711	2.668

For Flood Hazard (SB) sub-criterion of Hazard (TH) criterion, based on given weight the following results were obtained; For SB parameter based on 13.2 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 25 wt.% for this sub-criterion. So the sensitivity analysis results for Flood Hazard (SB) parameter are acceptable between 0-25 wt.% and can be seen in Table 7.10.

Table 7.10: Means and Standard Deviations for SB Parameter

Flood Hazard's (SB) Weight	Mean	Standard Deviation
0.132	2.949	1.183
0.000	2.998	1.058
0.250	2.907	1.334
0.500	2.812	1.728
0.750	2.717	2.175
1.000	2.626	2.647

For Tsunami Hazard (TS) sub-criterion of Hazard (TH) criterion, based on given weight the following results were obtained; For TS parameter based on 7.4 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is more than 25 wt.% for this sub-criterion. So the sensitivity analysis results for Tsunami

Hazard (TS) parameter are acceptable between 0-25 wt.% and can be seen in Table 7.11.

Table 7.11: Means and Standard Deviations for TS Parameter

Tsunami Hazard's (TS) Weight	Mean	Standard Deviation
0.074	2.949	1.183
0.000	2.767	1.301
0.250	3.387	0.946
0.500	4.010	0.800
0.750	4.632	0.962
1.000	5.252	1.323

For Fire Hazard (YN) sub-criterion of Hazard (TH) criterion, based on given weight the following results were obtained; For YN parameter based on 36.1 wt. % in the model, sensitivity analysis were applied for 0, 25, 50, 75, 100 wt.% respectively.

According to the visual results the significant changes occur when the weight is less than 25 wt.% and more than 75 wt.% for this sub-criterion. So the sensitivity analysis results for Fire Hazard (YN) parameter are acceptable between 25-75 wt.% and can be seen in Table 7.12.

Table 7.12: Means and Standard Deviations for YN Parameter

Fire Hazard's (YN) Weight	Mean	Standard Deviation
0.361	2.949	1.183
0.000	3.885	1.550
0.250	3.239	1.283
0.500	2.592	1.082
0.750	1.946	0.987
1.000	1.299	1.029

8. RESULTS AND CONCLUSIONS

In this study, firstly, the problem of locating temporary shelter areas after a disaster is addressed. Mathematical models for optimum shelter locations were developed to select the best shelter area locations from a set of criteria. The model determines shelter area locations and matches population areas with the nearest open shelter while taking shelter area utilizations into account. Result map was provided for Istanbul city, which included all the criteria (Strong infrastructure, enough capacity, being accessible etc.) and sub-criteria with their importance to offer the suitable areas for temporary shelter location.

In the second part of this study, the sensitivity analysis is applied for all criteria and sub-criteria by using combination of AHP and GIS systems and the explanations are presented in the subsequent paragraph.

Sensitivity analysis was applied on optimum shelter locations model for Istanbul city. Each criterion including AL, ER, TH, TO, KA, AK, and all criteria for the 0,10, 20, 30, 40, 50, 60, 70, 80, 90, 100 wt.% is considered as the various terms. It's notable to mention that the results are presented for Sub-Criteria terms including DP, TS, HY, SB, KM, YN ,IL, SU, KN, EL , GZ, KR, DN , HV, DM in 0, 25, 50, 75, 100 wt. %. These results are shown in the Appendix tables (Table A.1 to Table A.21).

By means of AHP system, 135 sensivity analysis are carried out on the available parameters in the model based on weight value. Regard that, 60 analysis are based on main parameters and 75 analysis are done on sub-criteria.

In Appendix (Figure A.1 to Figure A.145) all results of the sensitivity analysis in GIS environment are given visually. For example, according to these maps, for TH parameter sensitivity analysis are undertaken; the figures between A.46 to A.56 show evaluation based on weight variation.

By integrating visual results (maps) and numeric results (Raster Compare results), the acceptable sensitivity intervals for all criteria and sub-criteria are obtained and presented in the Table 8.1 and Table 8.2:

Table 8.1: Sensitivity Analysis Result for Main Criteria

Main Criterion	Weight in Model	Sensitivity Interval
AL (Infrastructure)	17.3%	10% to 40%
ER (Accessibility)	20.7%	20% to 70%
TH (Hazard)	31.3%	30% to 50%
TO (Topography)	9.5%	40% to 50%
KA (Capacity)	15.5%	0% to 20%
AK (Land Usage)	5.7%	0% to 50%

Table 8.2: Sensitivity Analysis Result for Sub-Criteria

Sub-Criterion	Weight in Model	Sensitivity Interval
DP (Earthquake Hazard)	7.4%	0% to 25%
TS (Tsunami Hazard)	7.4%	0% to 25%
HY (Landslide Hazard)	13.2%	0% to 25%
SB (Flood Hazard)	13.2%	0% to 25%
KM (Chemical Hazard)	22.7%	0% to 50%
YN (Fire Hazard)	36.1%	25% to 75%
IL (Communication)	6.3%	0% to 50%
SU (Drinking Water)	23.3%	0% to 50%
KN (Waste Water Lines)	48.9%	25% to 50%
EL (Electricity Lines)	15.2%	0% to 25%
GZ (Gas Lines)	6.3%	0% to 50%
KR (Roads and Highways)	54.2%	25% to 75%
DN (Marine Ports)	8.5%	0% to 75%
HV (Heliports)	14%	0% to 50%
DM (Railways)	23.3%	0% to 75%

For all types of models with different parameters, in order to data availability this method could be practical by merging GIS and AHP systems. It’s note that, during the analysis process, the local standards must be considered as inevitable term for consideration.

The most important challenge in these kinds of projects is gathering the correct data from the local references; fortunately, the data were provided by my supervisor which are reliable enough.It’s noteworthy that these kinds of data are not easily accessable from local metropolitan municipality directorate of earthquake and ground analysis.

Results of this study can be useful for researchers who want to continue this study, because the results of sensitivity analysis which are reached from this study can be added as a new toolbox in the ArcGIS software to show the limitations of criteria weight values for the users who want to change the weight of criteria and the users who try to get a new or a more complete model of certain criteria.

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APPENDICES

APPENDIX A: Maps
APPENDIX B: Tables

APPENDIX A - Maps

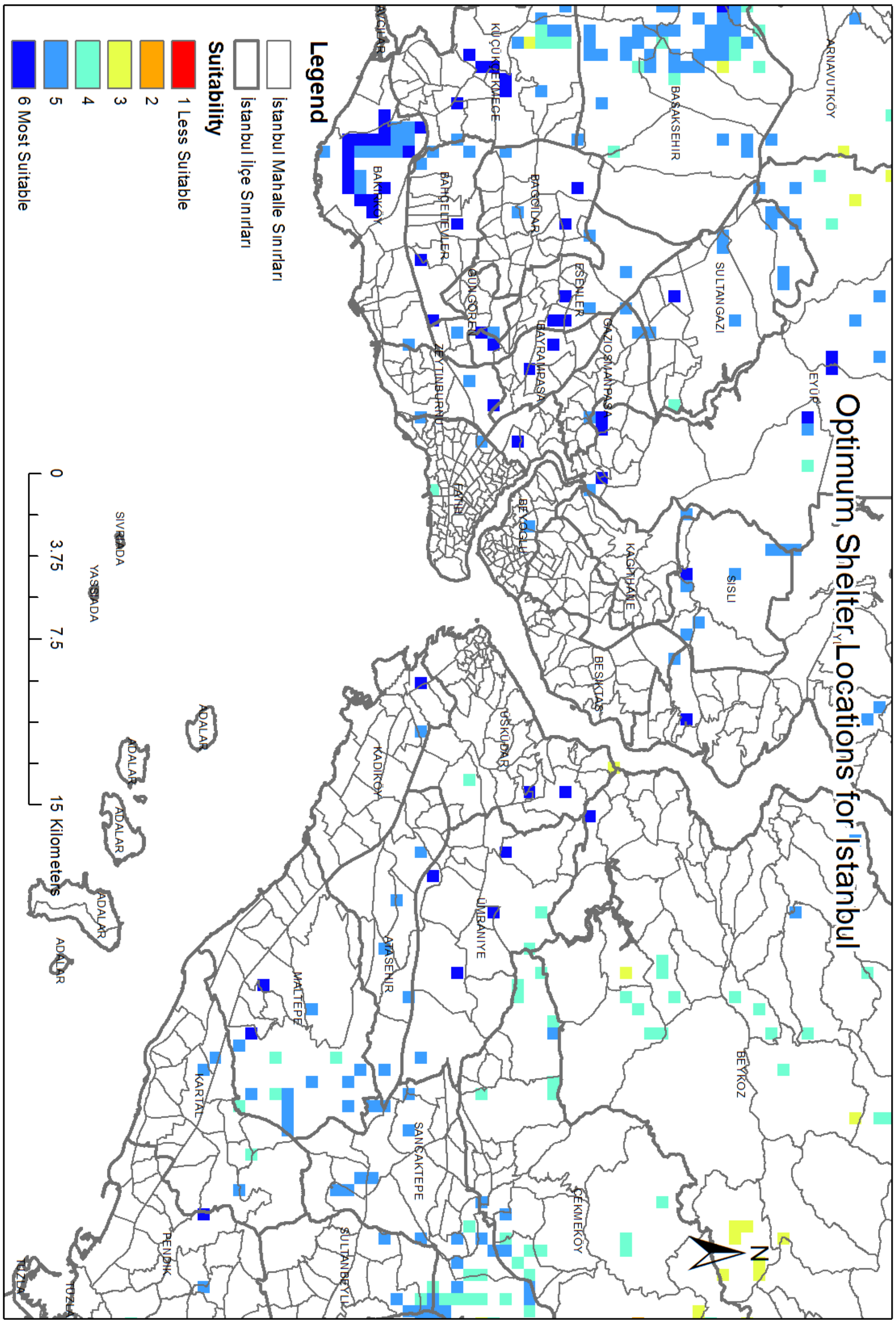

Figure A.1 : Optimum shelter locations for Istanbul.

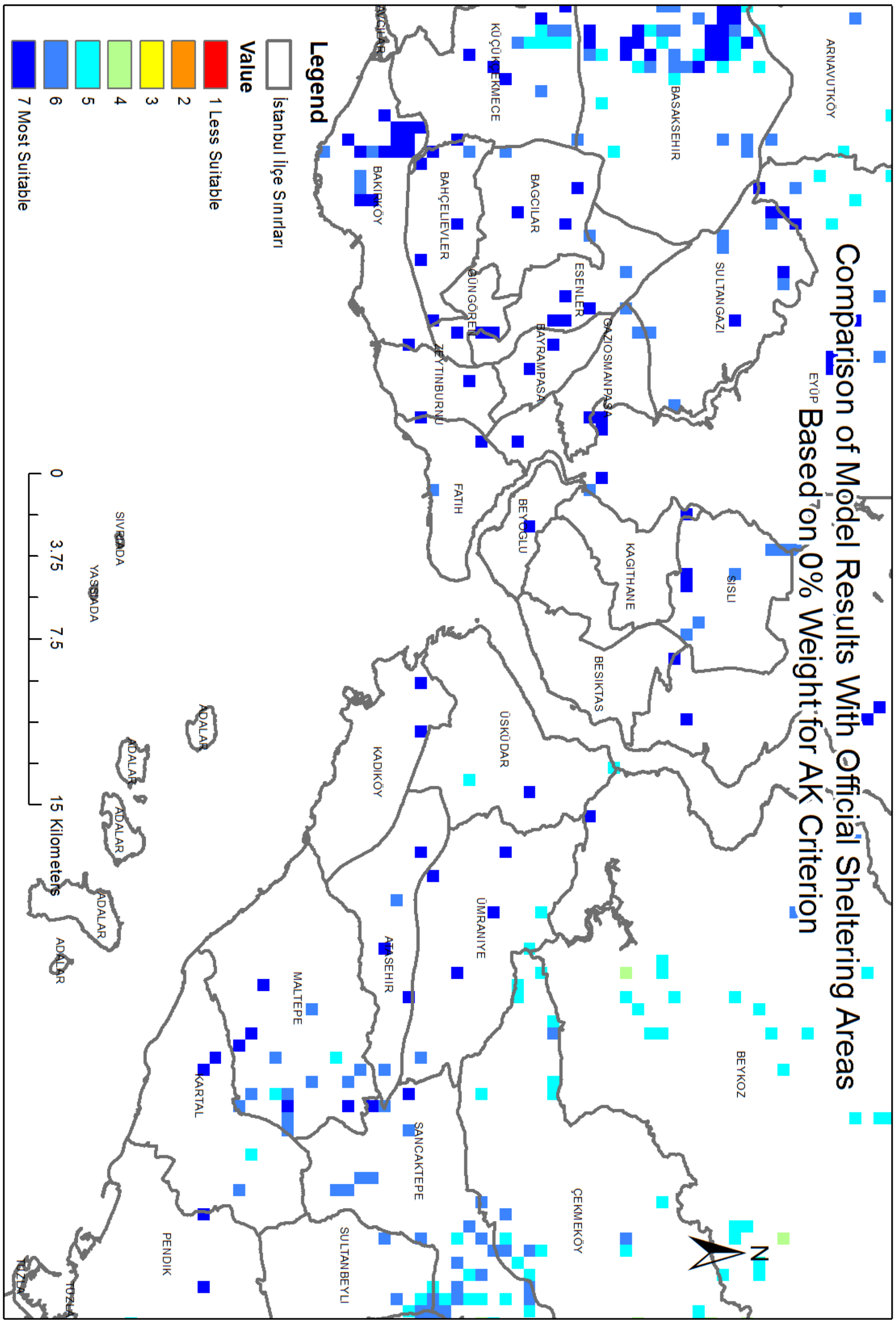

Figure A.2 : Comparison of model results with official sheltering areas based on 0% weight for AK criterion

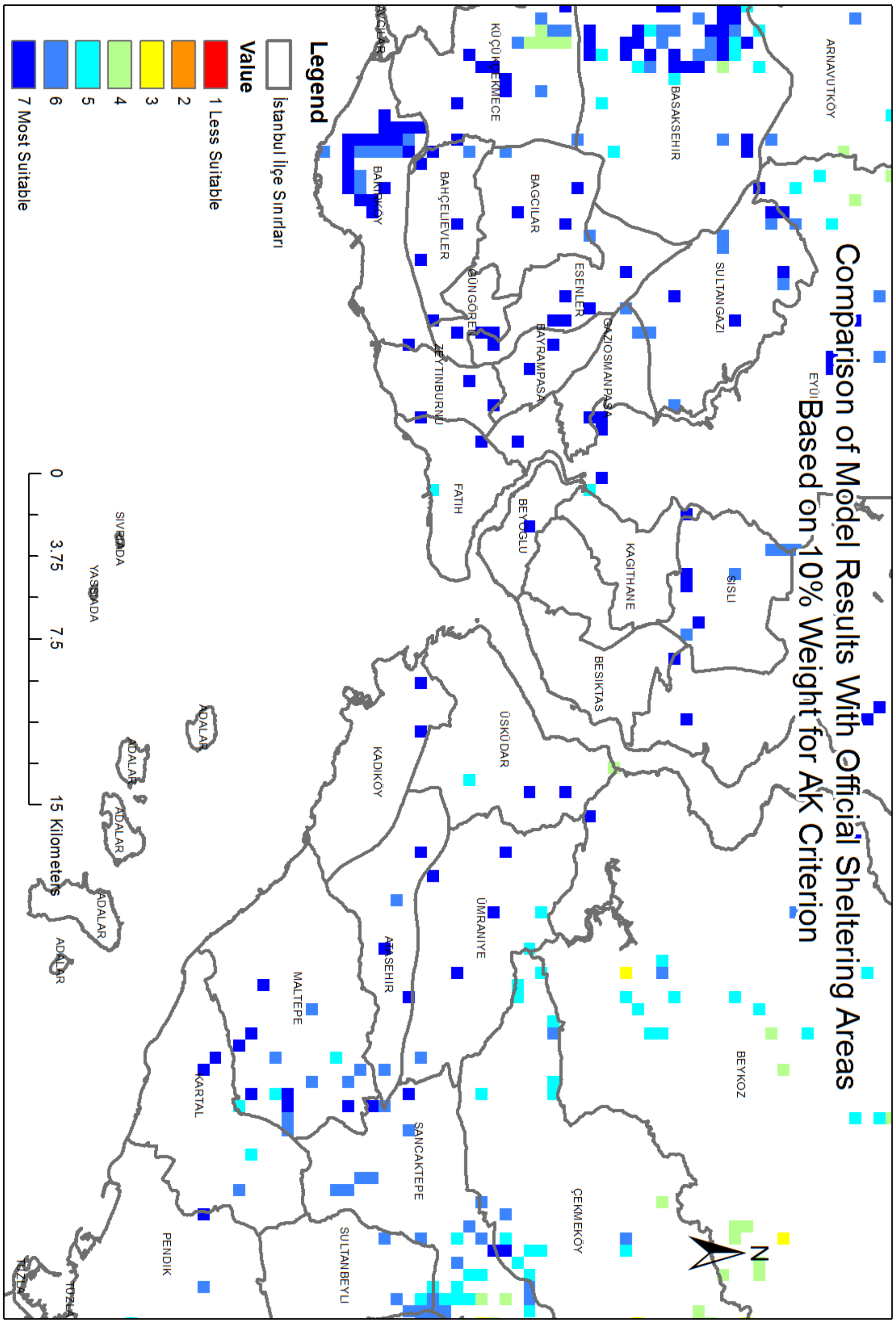

Figure A.3 : Comparison of model results with official sheltering areas based on 10% weight for AK criterion

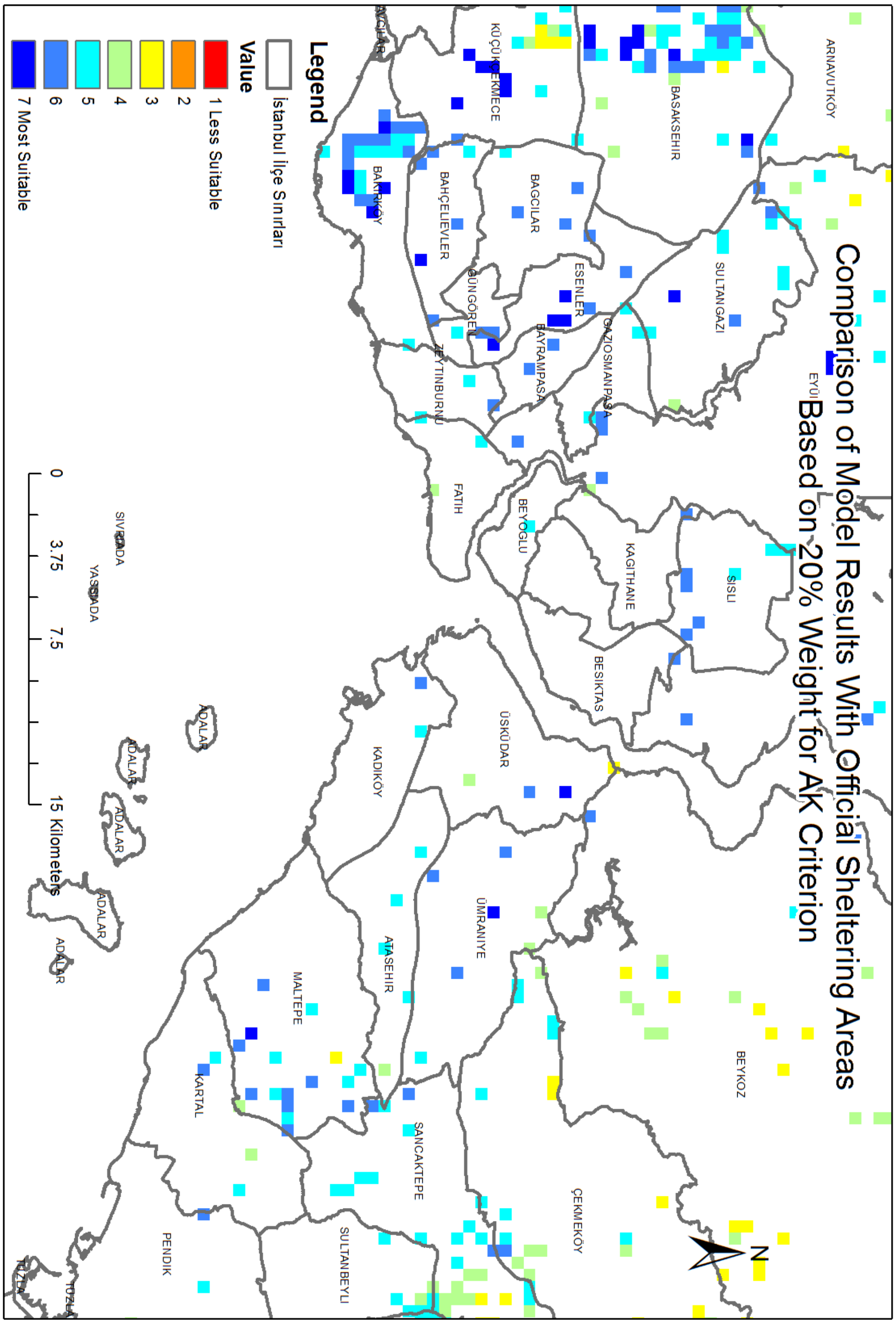

Figure A.4 : Comparison of model results with official sheltering areas based on 20% weight for AK criterion

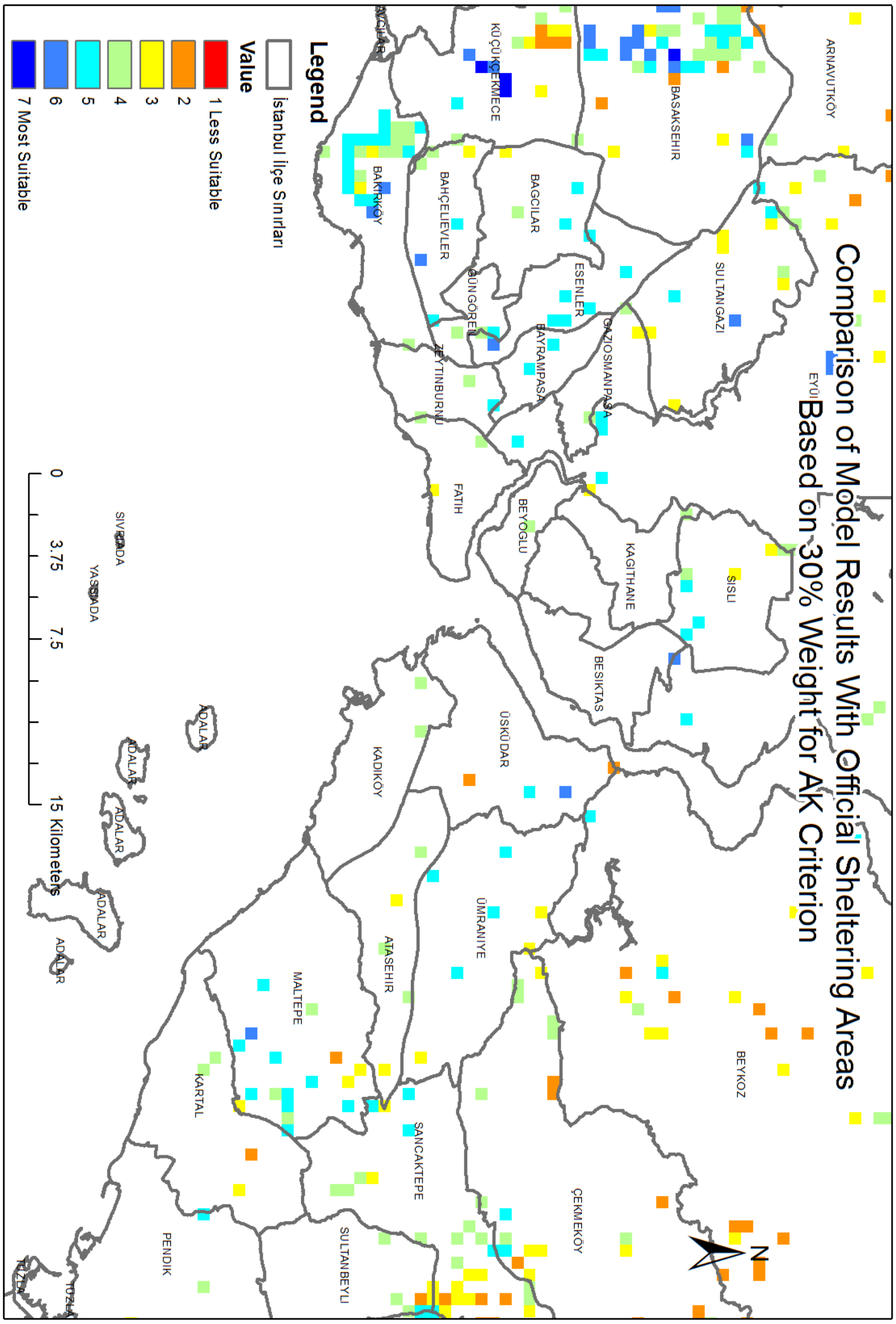

Figure A.5 : Comparison of model results with official sheltering areas based on 30% weight for AK criterion

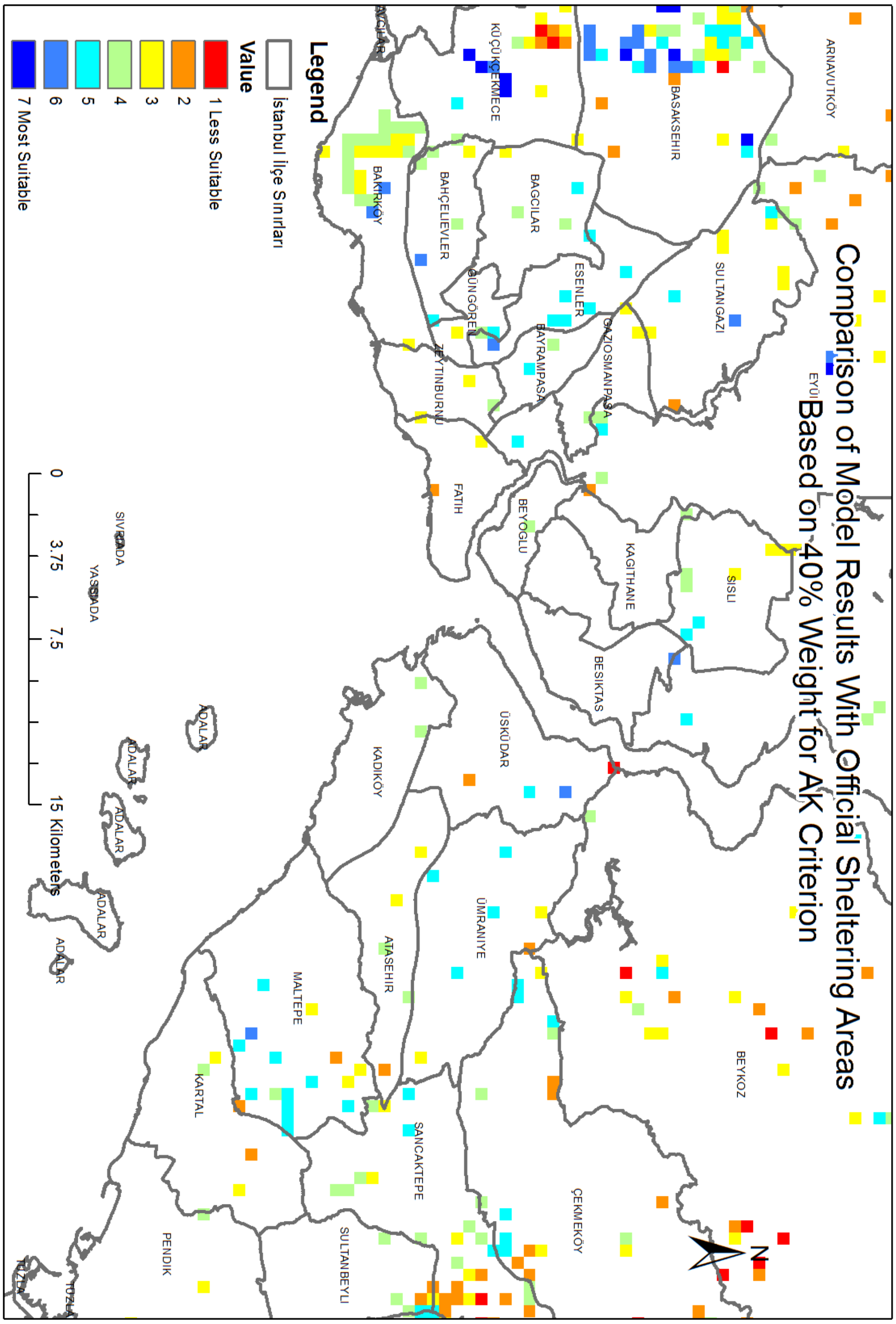

Figure A.6 : Comparison of model results with official sheltering areas based on 40% weight for AK criterion

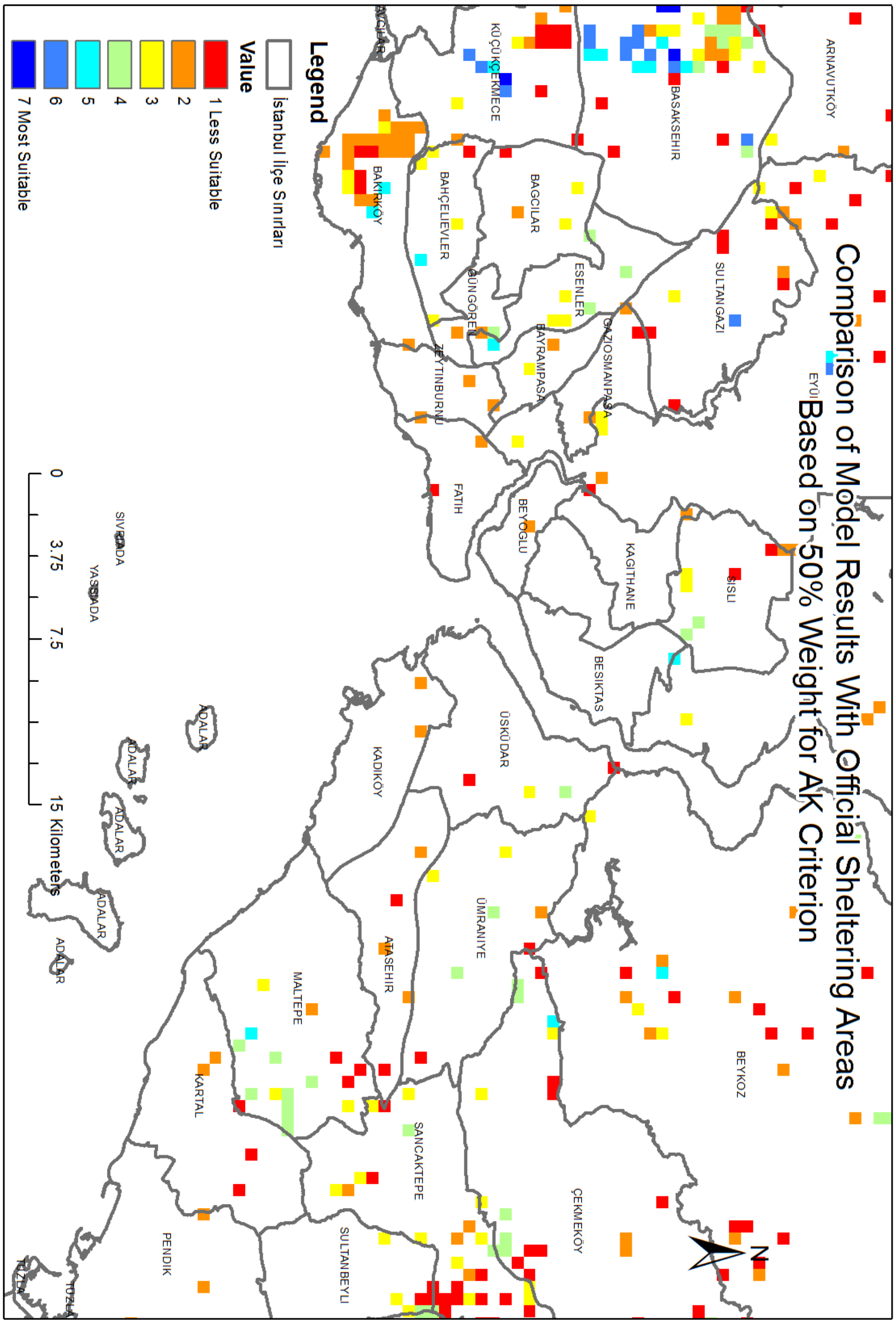

Figure A.7 : Comparison of model results with official sheltering areas based on 50% weight for AK criterion

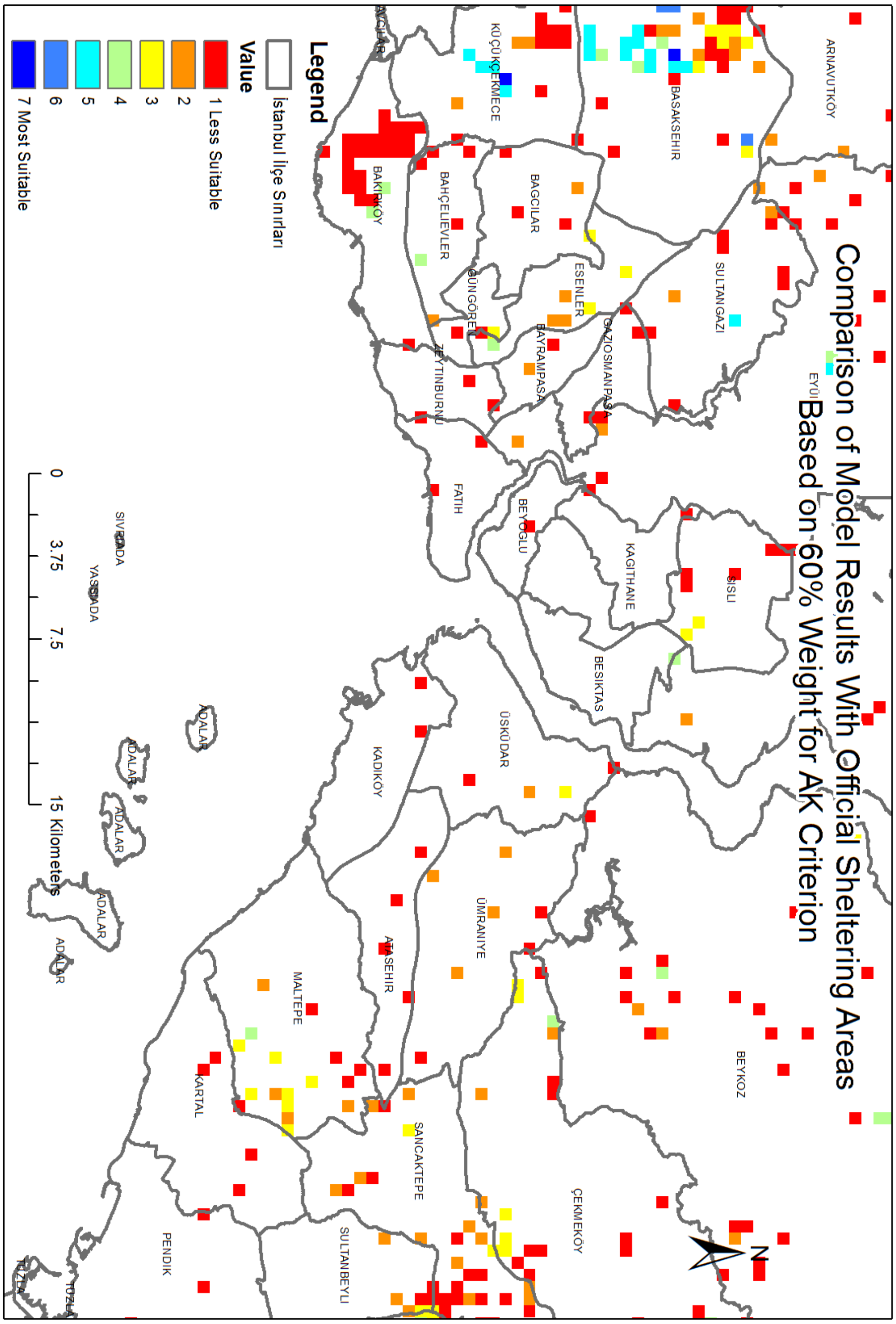

Figure A.8 : Comparison of model results with official sheltering areas based on 60% weight for AK criterion

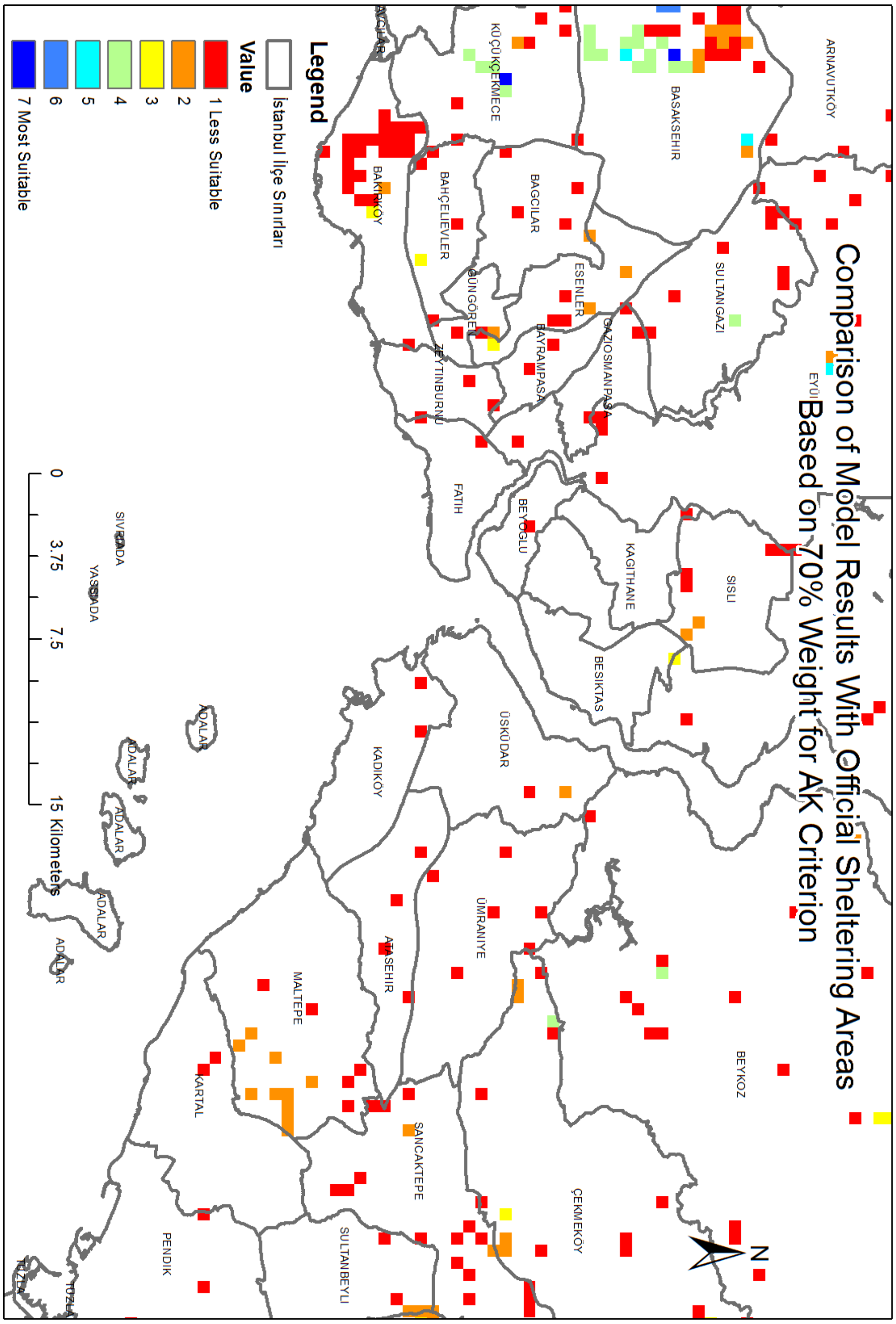

Figure A.9 : Comparison of model results with official sheltering areas based on 70% weight for AK criterion

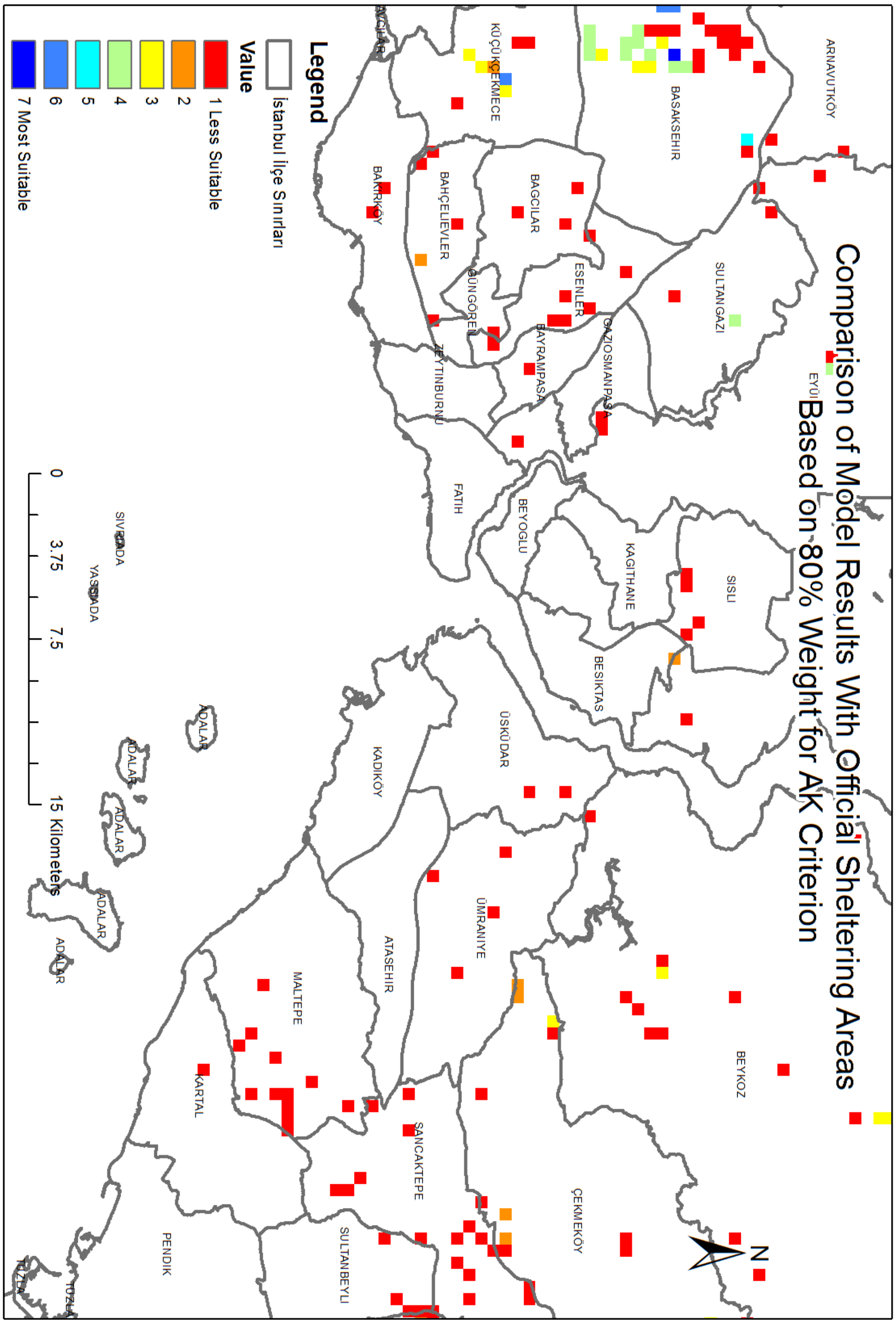

Figure A.10 : Comparison of model results with official sheltering areas based on 80% weight for AK criterion

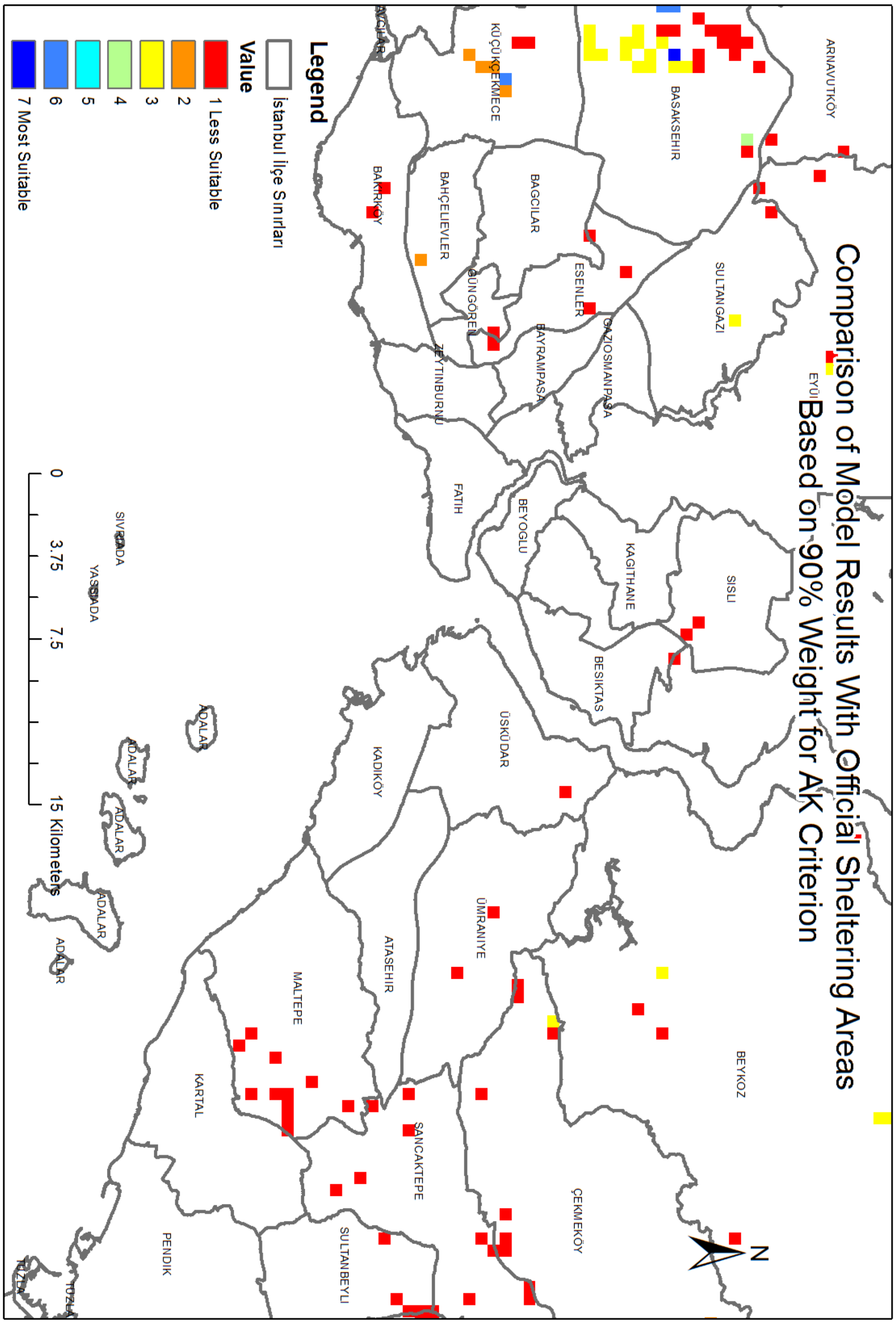

Figure A.11 : Comparison of model results with official sheltering areas based on 90% weight for AK criterion

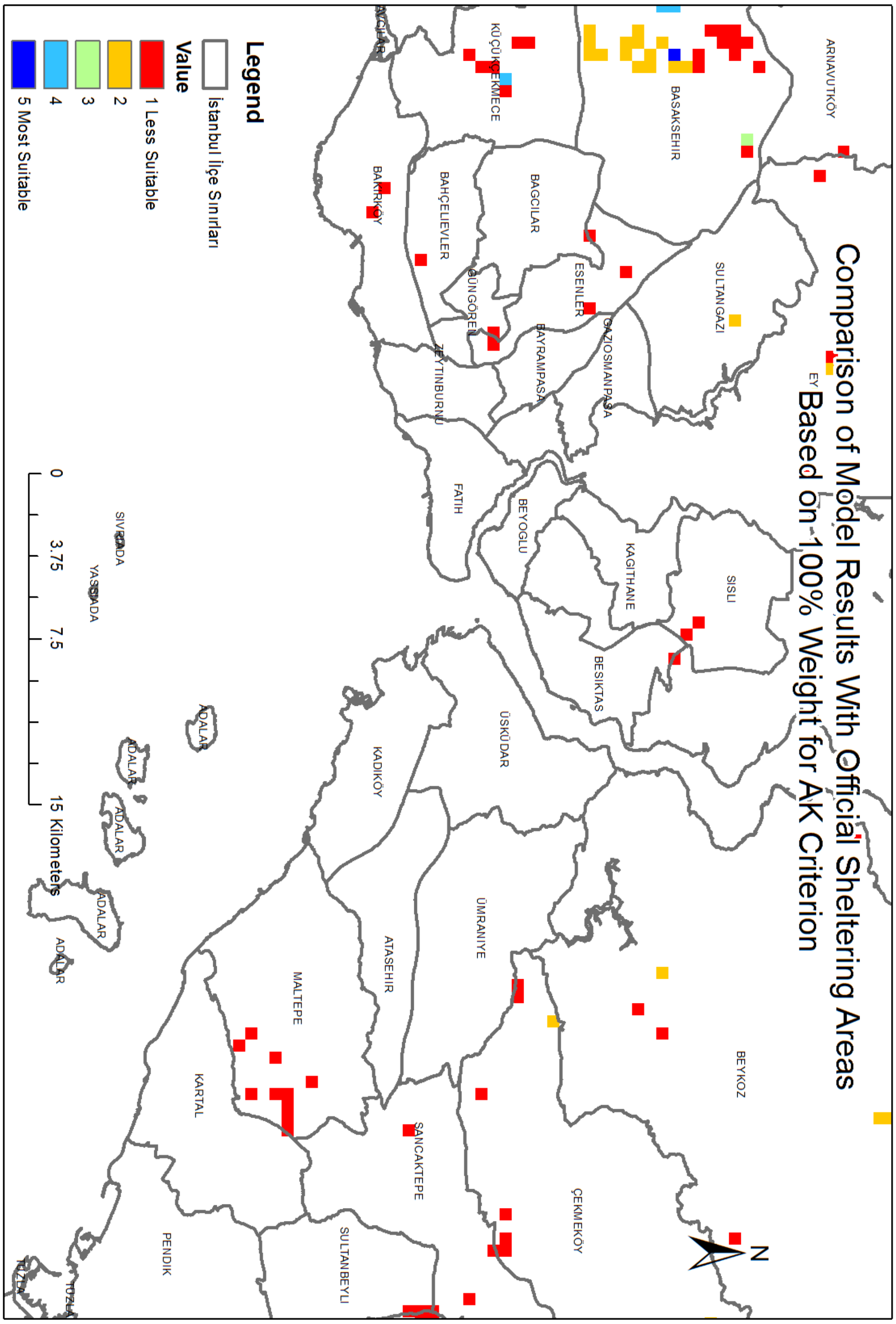

Figure A.12 : Comparison of model results with official sheltering areas based on 100% weight for AK criterion

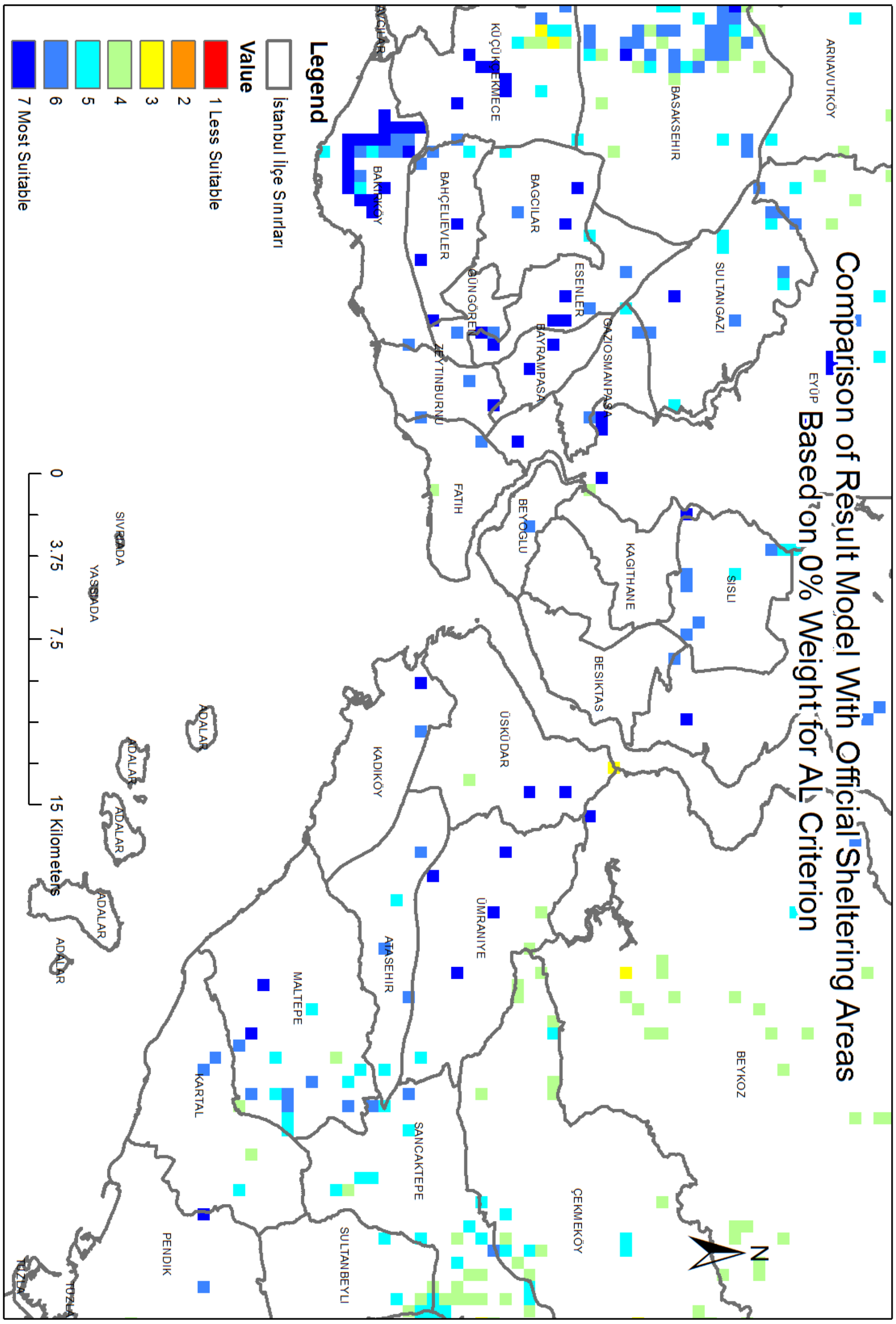

Figure A.13 : Comparison of model results with official sheltering areas based on 0% weight for AL criterion

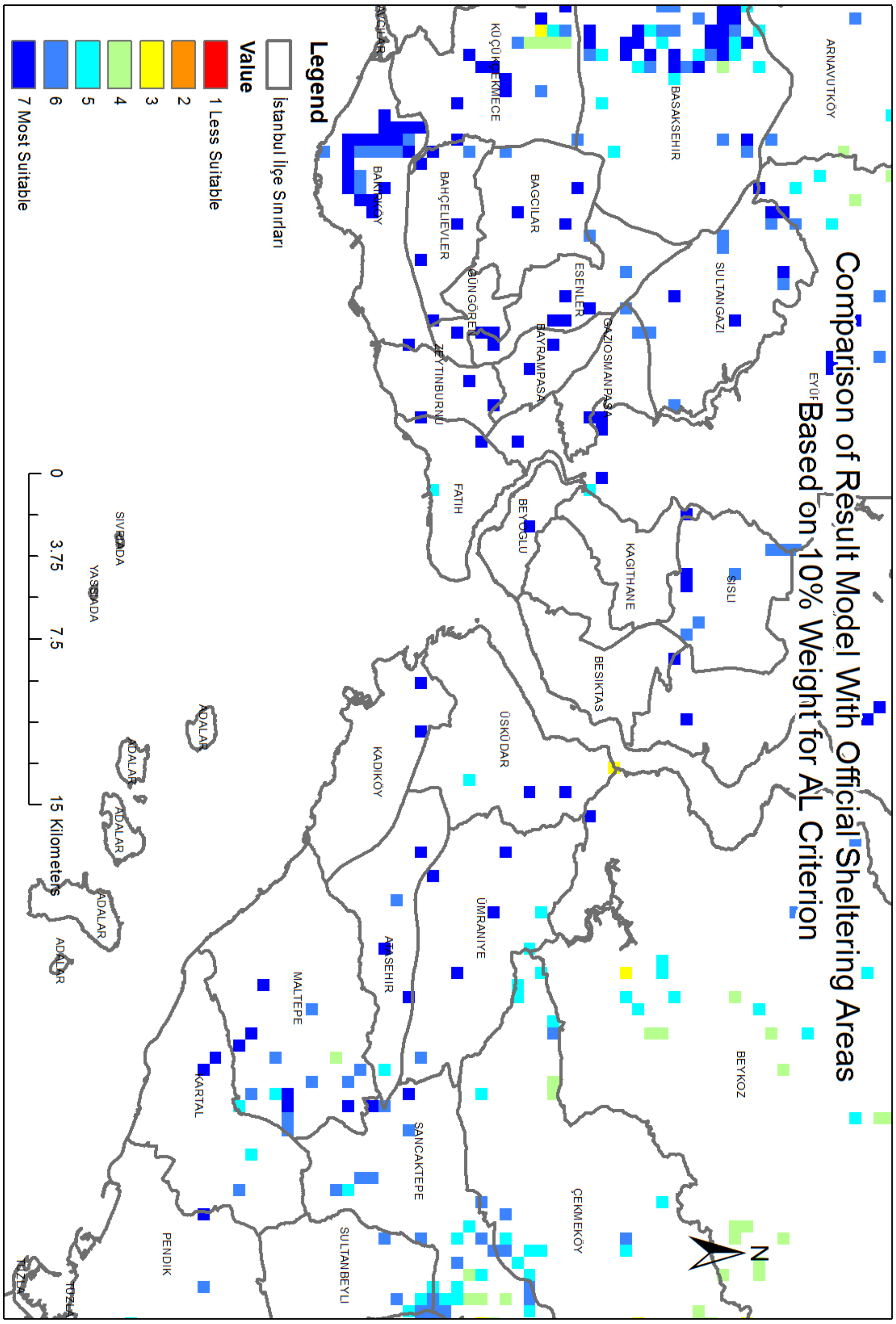

Figure A.14 : Comparison of model results with official sheltering areas based on 10% weight for AL criterion

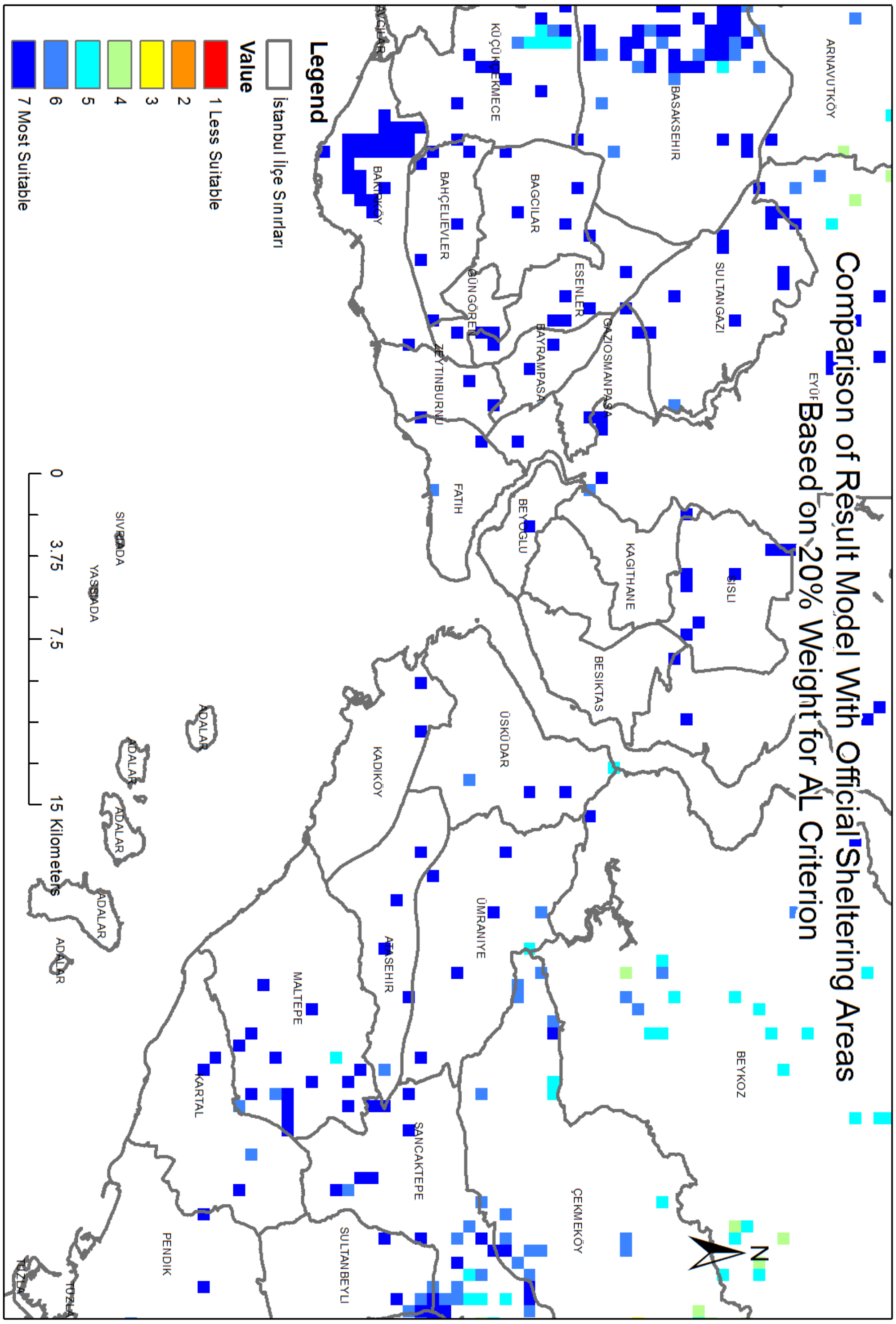

Figure A.15 : Comparison of model results with official sheltering areas based on 20% weight for AL criterion

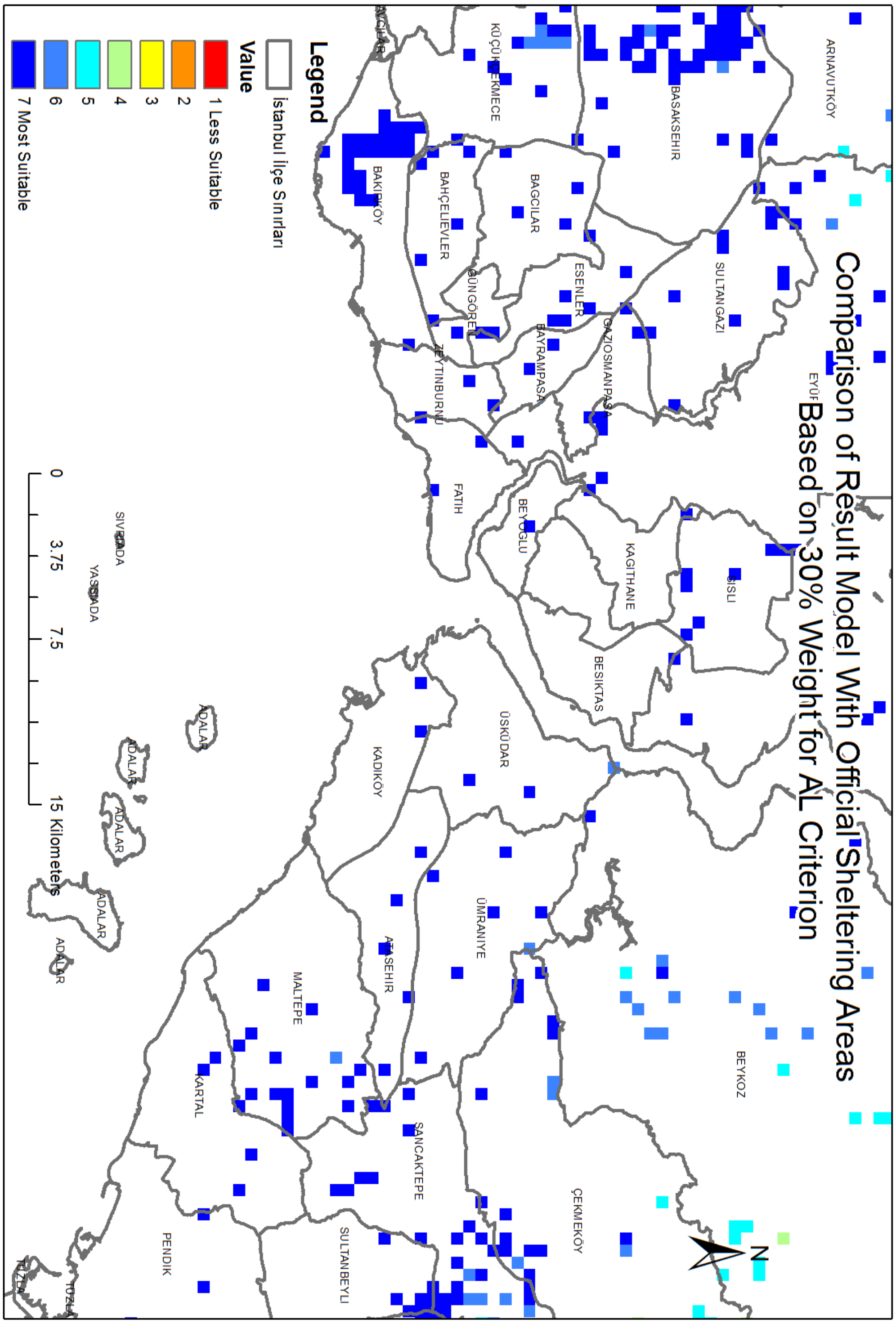

Figure A.16 : Comparison of model results with official sheltering areas based on 30% weight for AL criterion

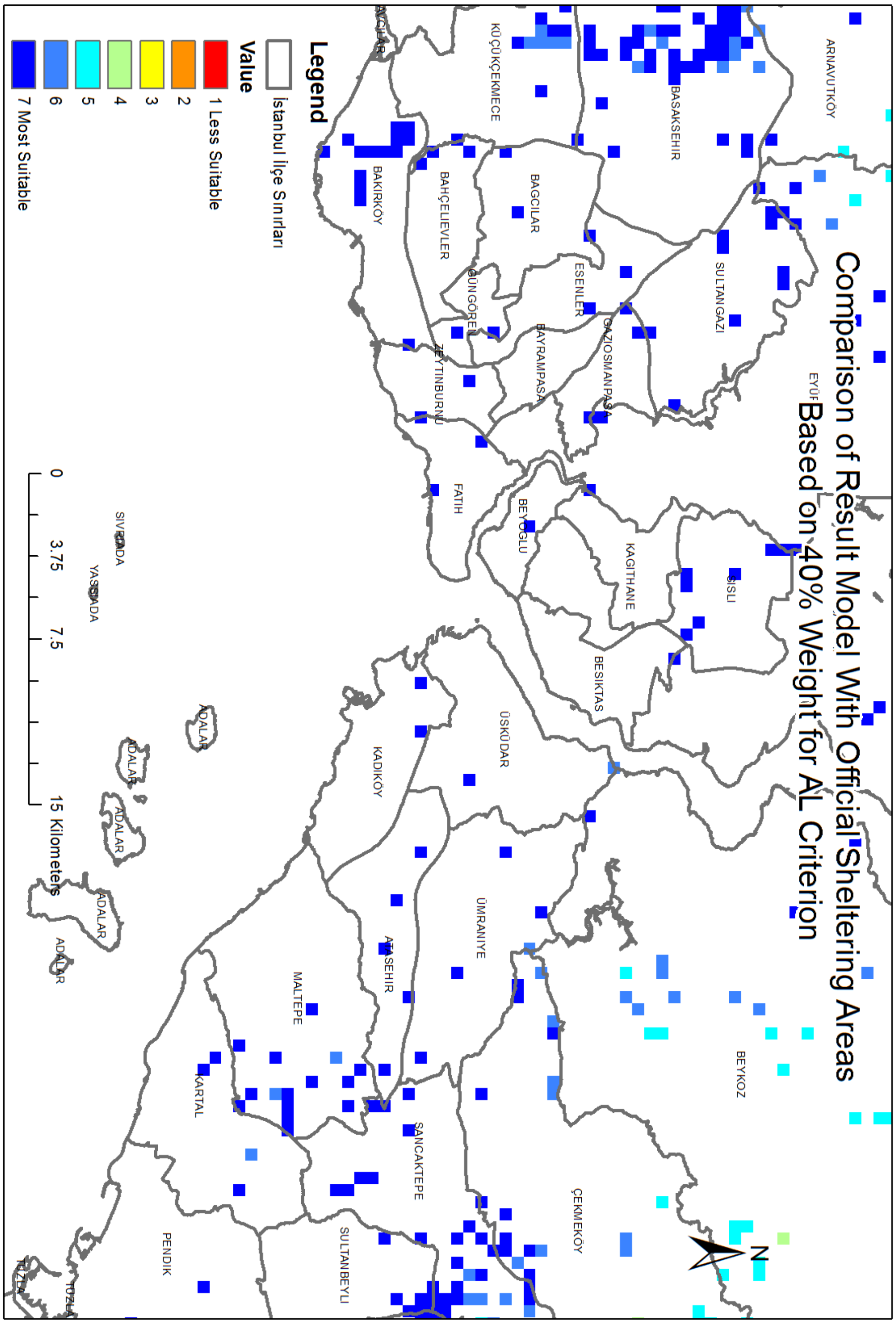

Figure A.17 : Comparison of model results with official sheltering areas based on 40% weight for AL criterion

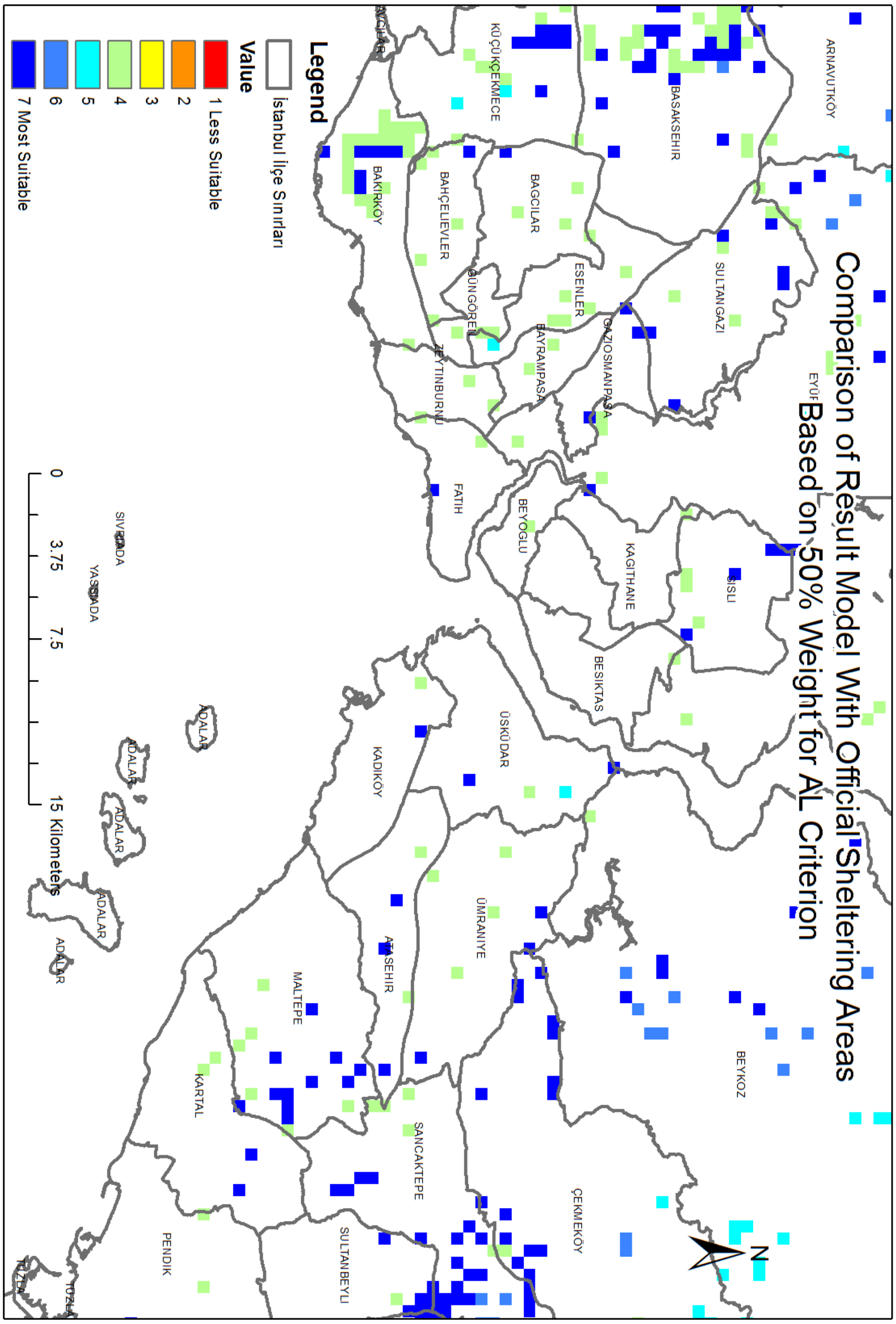

Figure A.18 : Comparison of model results with official sheltering areas based on 50% weight for AL criterion

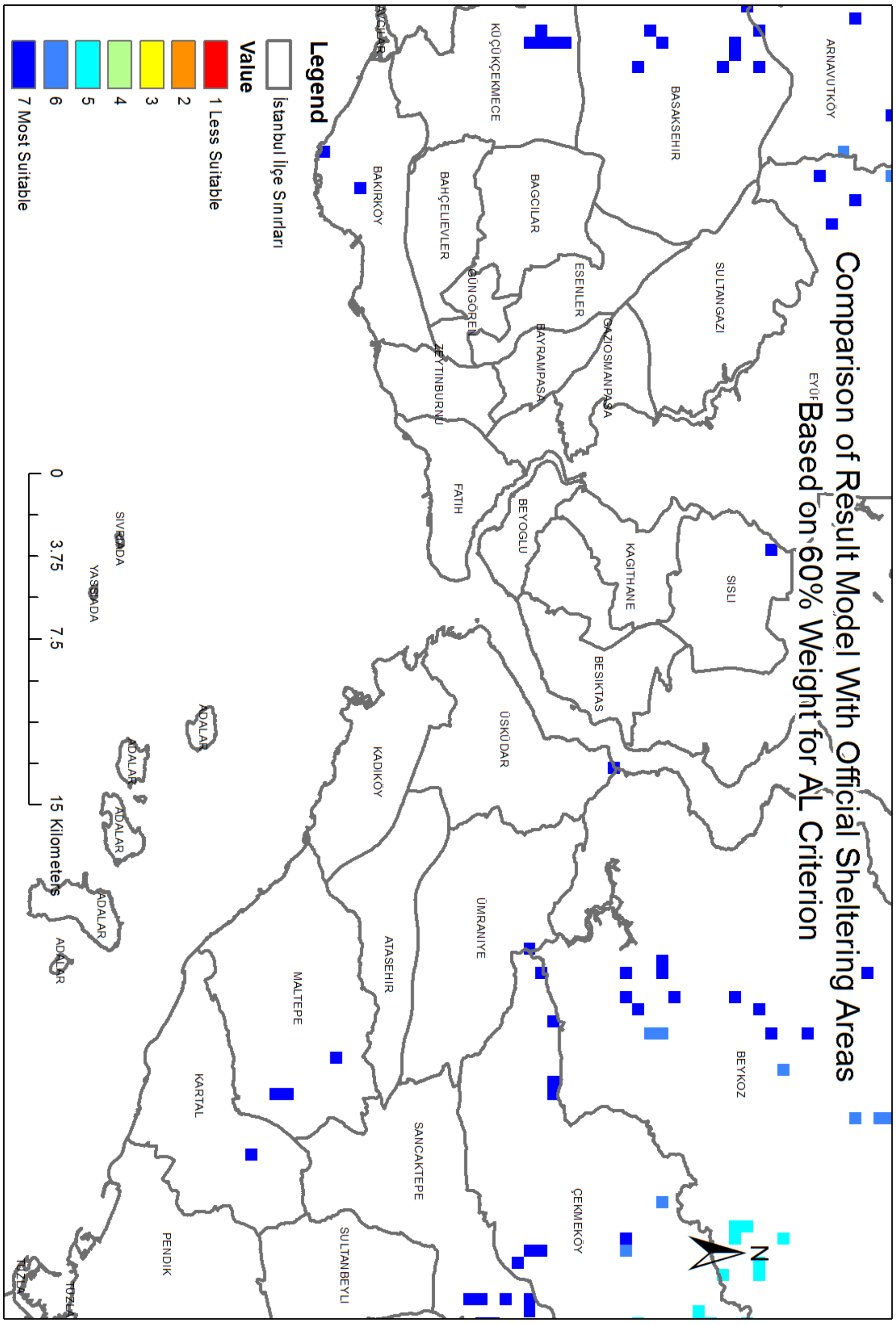

Figure A.19 : Comparison of model results with official sheltering areas based on 60% weight for AL criterion

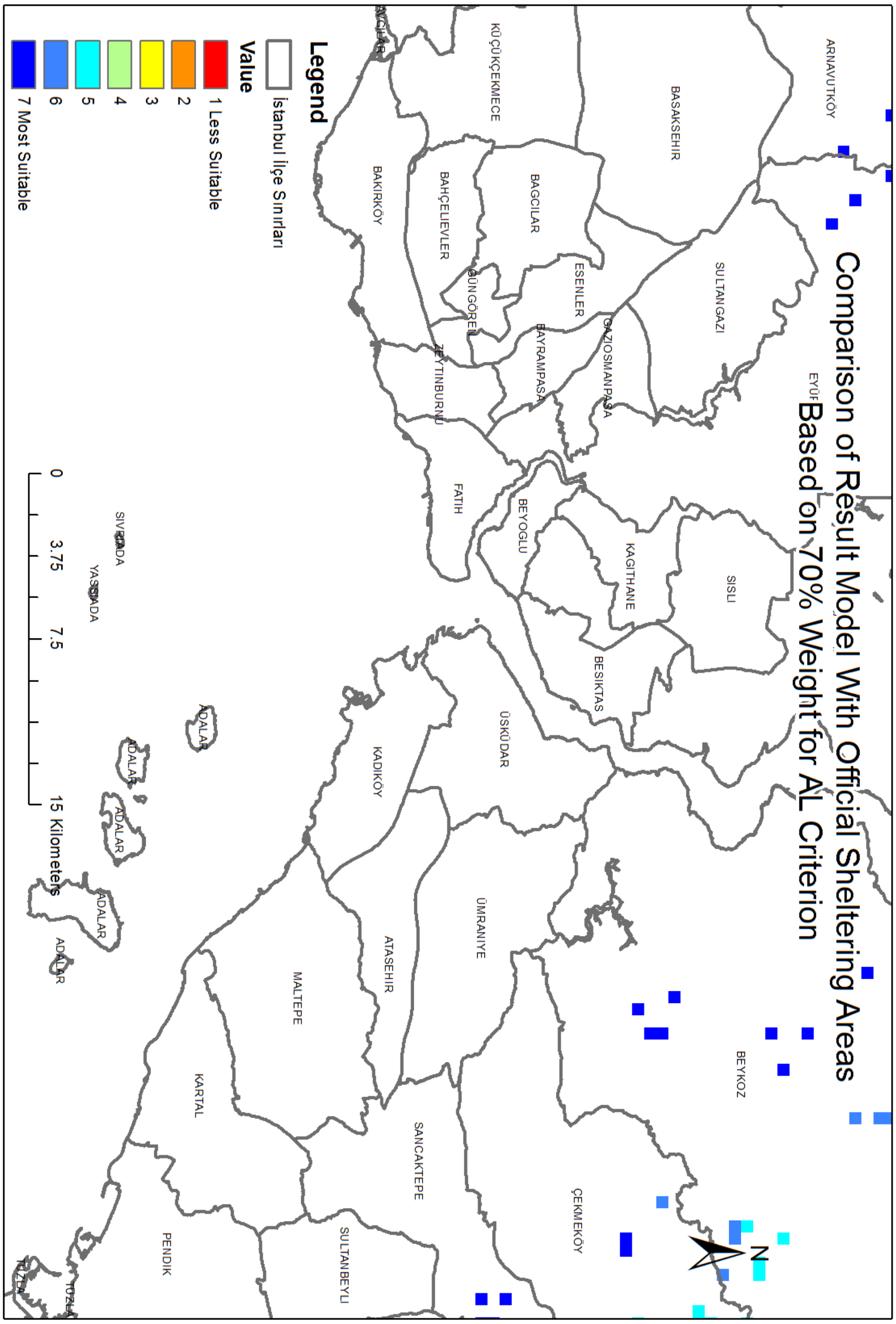

Figure A.20 : Comparison of model results with official sheltering areas based on 70% weight for AL criterion

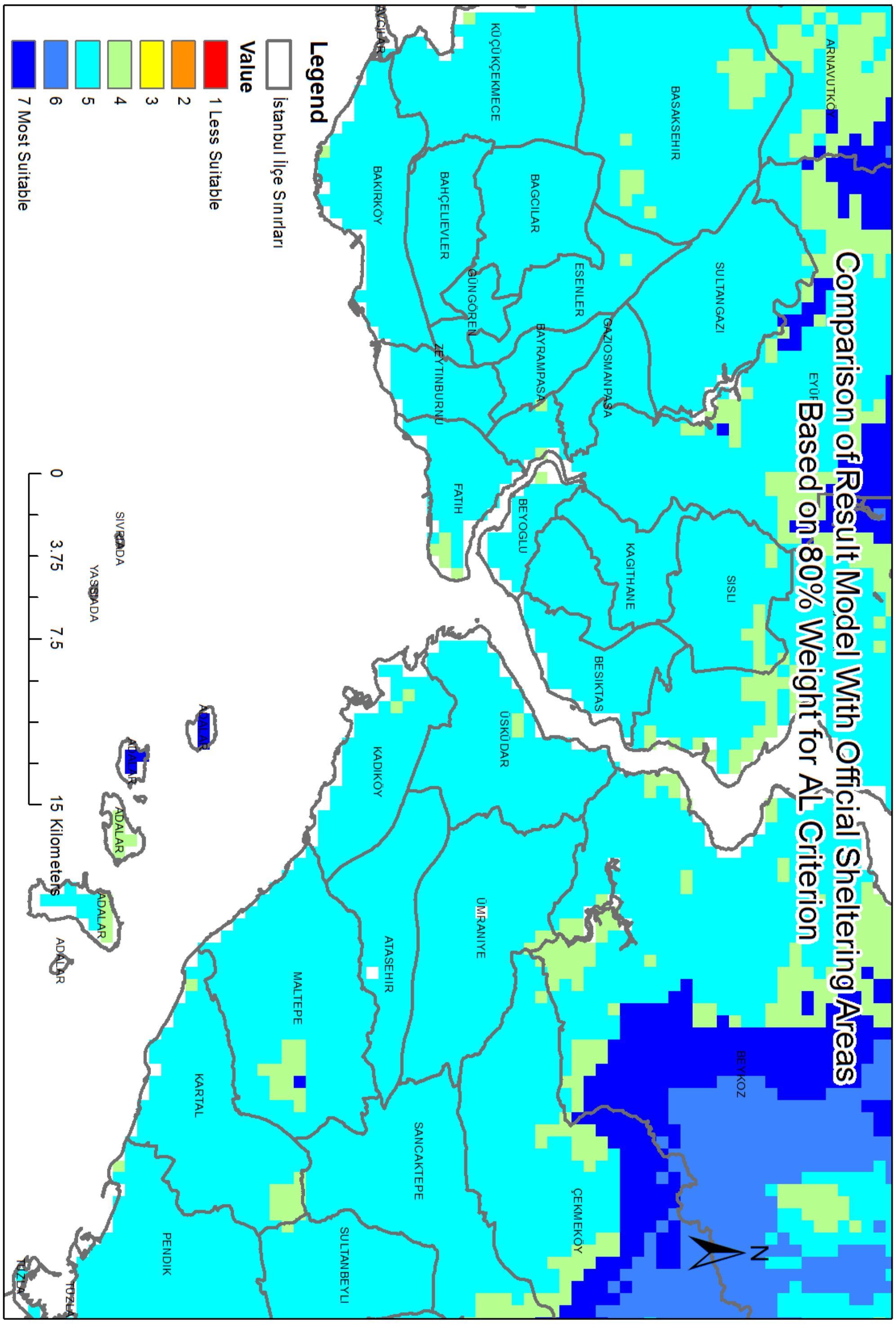

Figure A.21 : Comparison of model results with official sheltering areas based on 80% weight for AL criterion

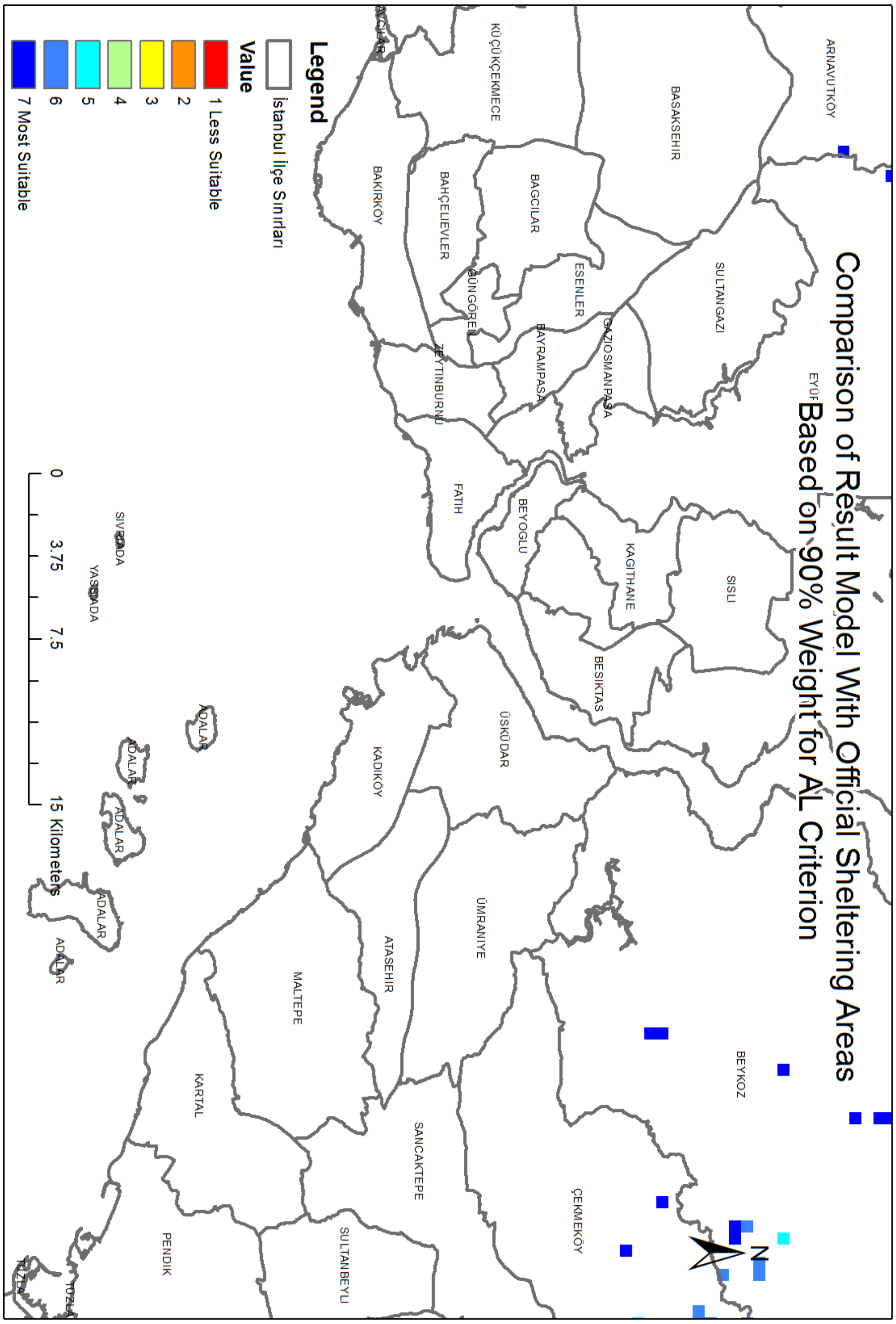

Figure A.22 : Comparison of model results with official sheltering areas based on 90% weight for AL criterion

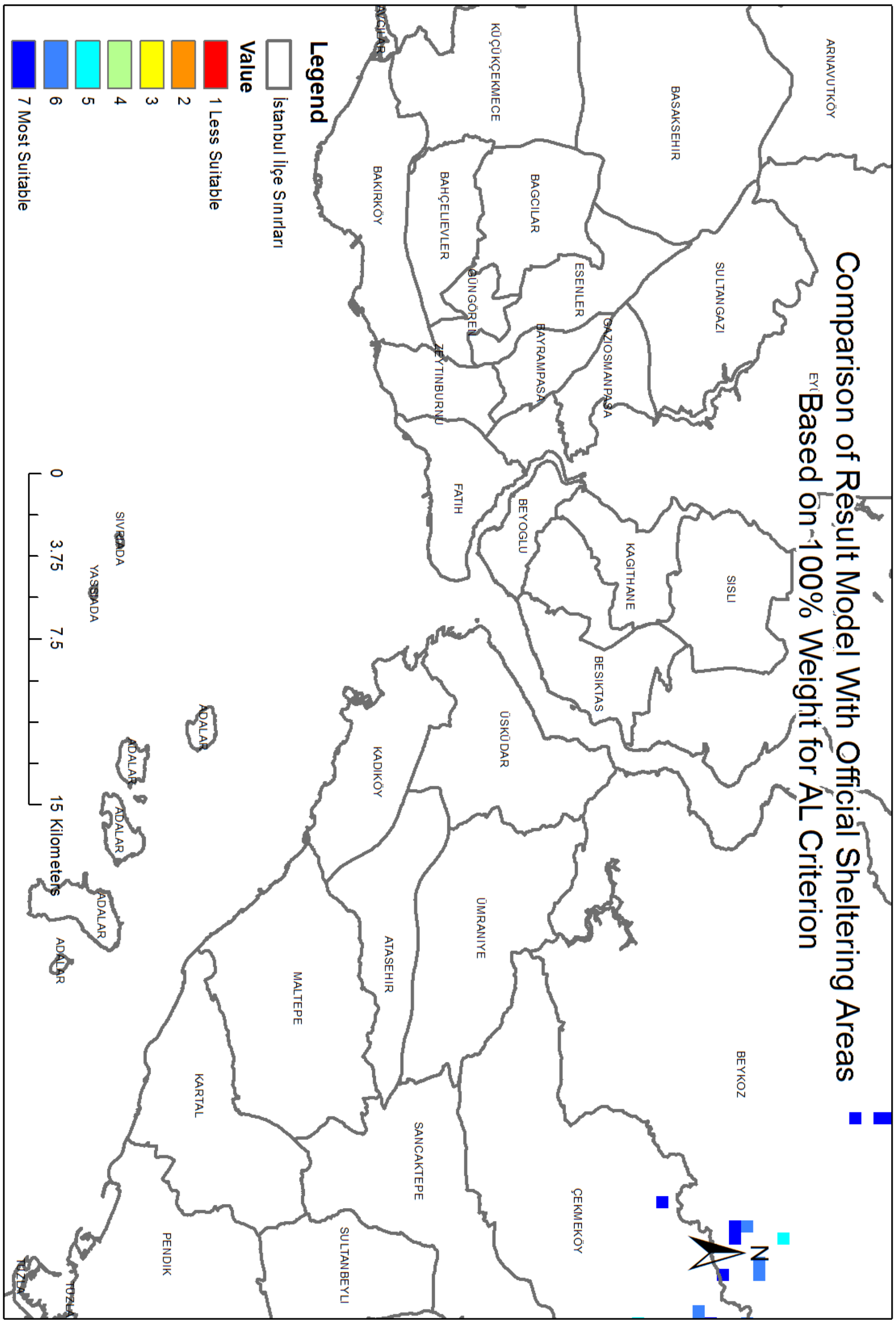

Figure A.23 : Comparison of model results with official sheltering areas based on 100% weight for AL criterion

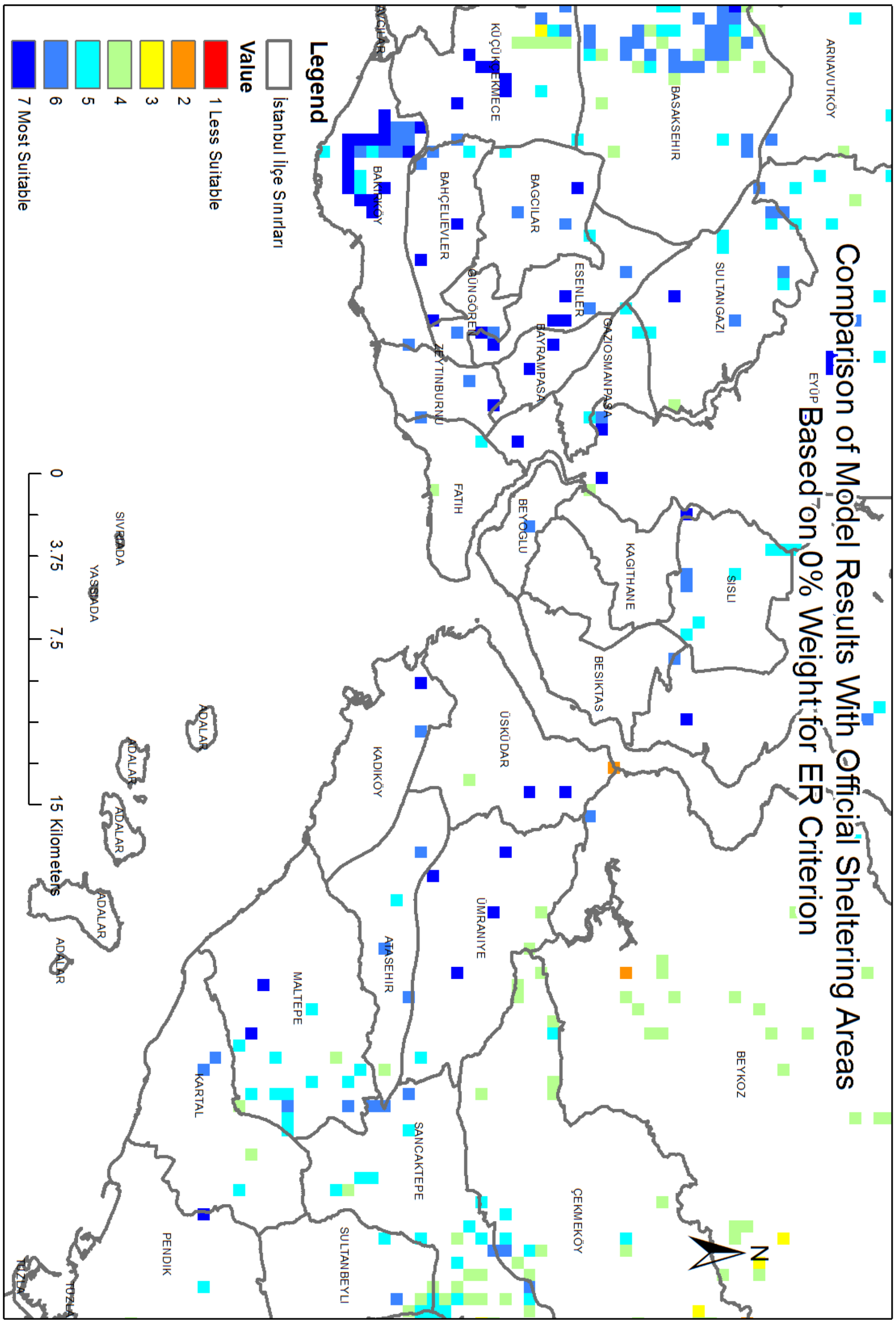

Figure A.24 : Comparison of model results with official sheltering areas based on 0% weight for ER criterion

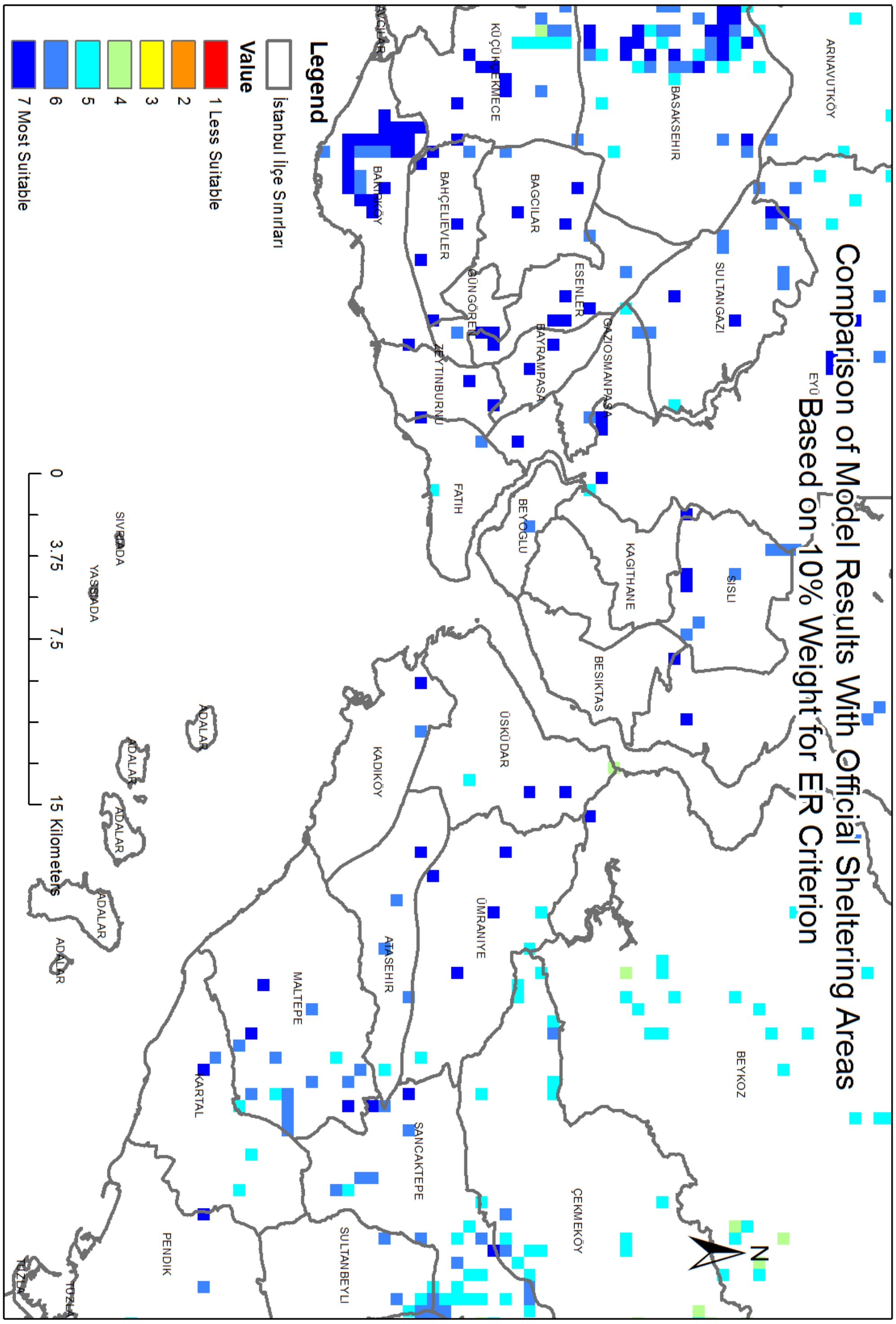

Figure A.25 : Comparison of model results with official sheltering areas based on 10% weight for ER criterion

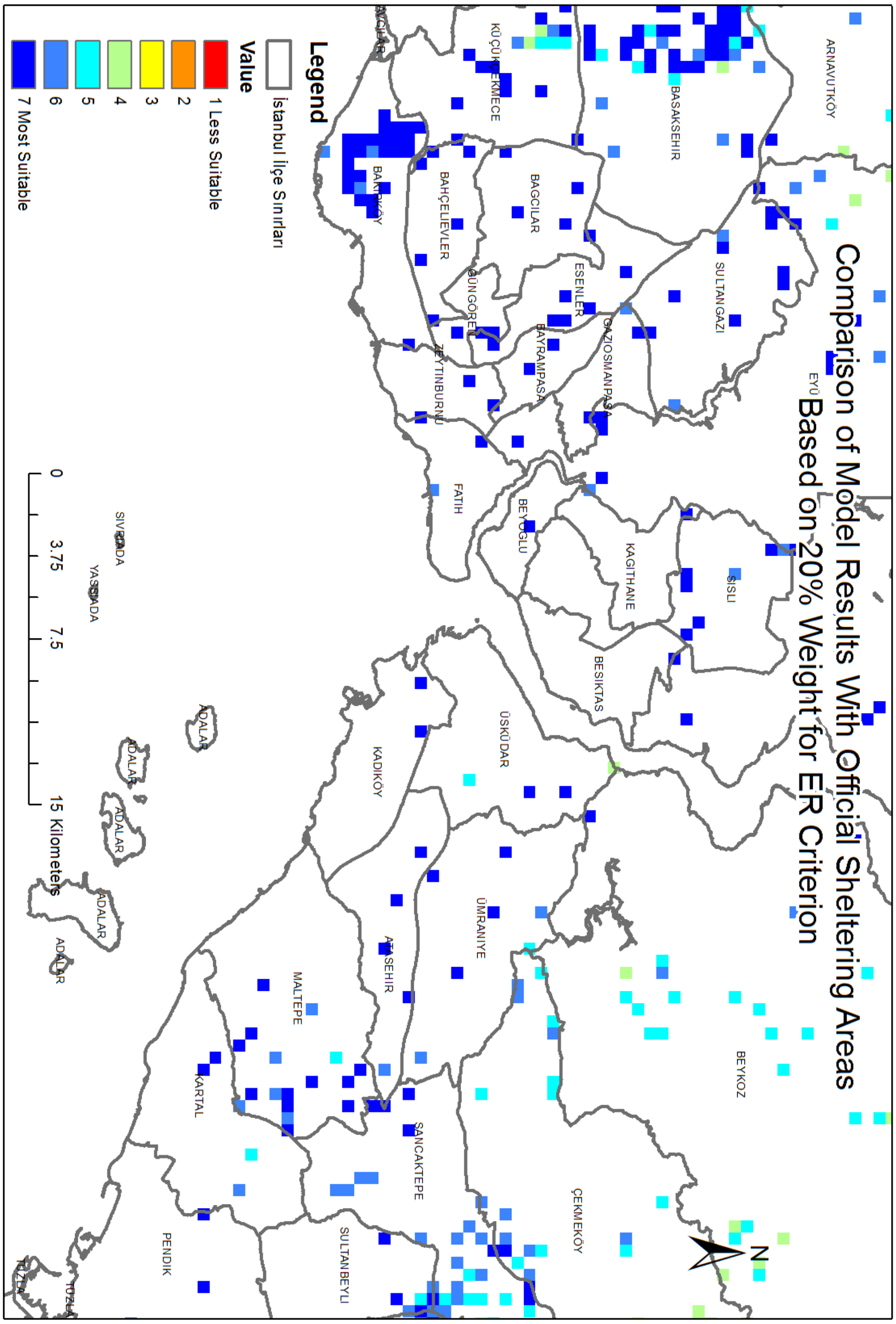

Figure A.26 : Comparison of model results with official sheltering areas based on 20% weight for ER criterion

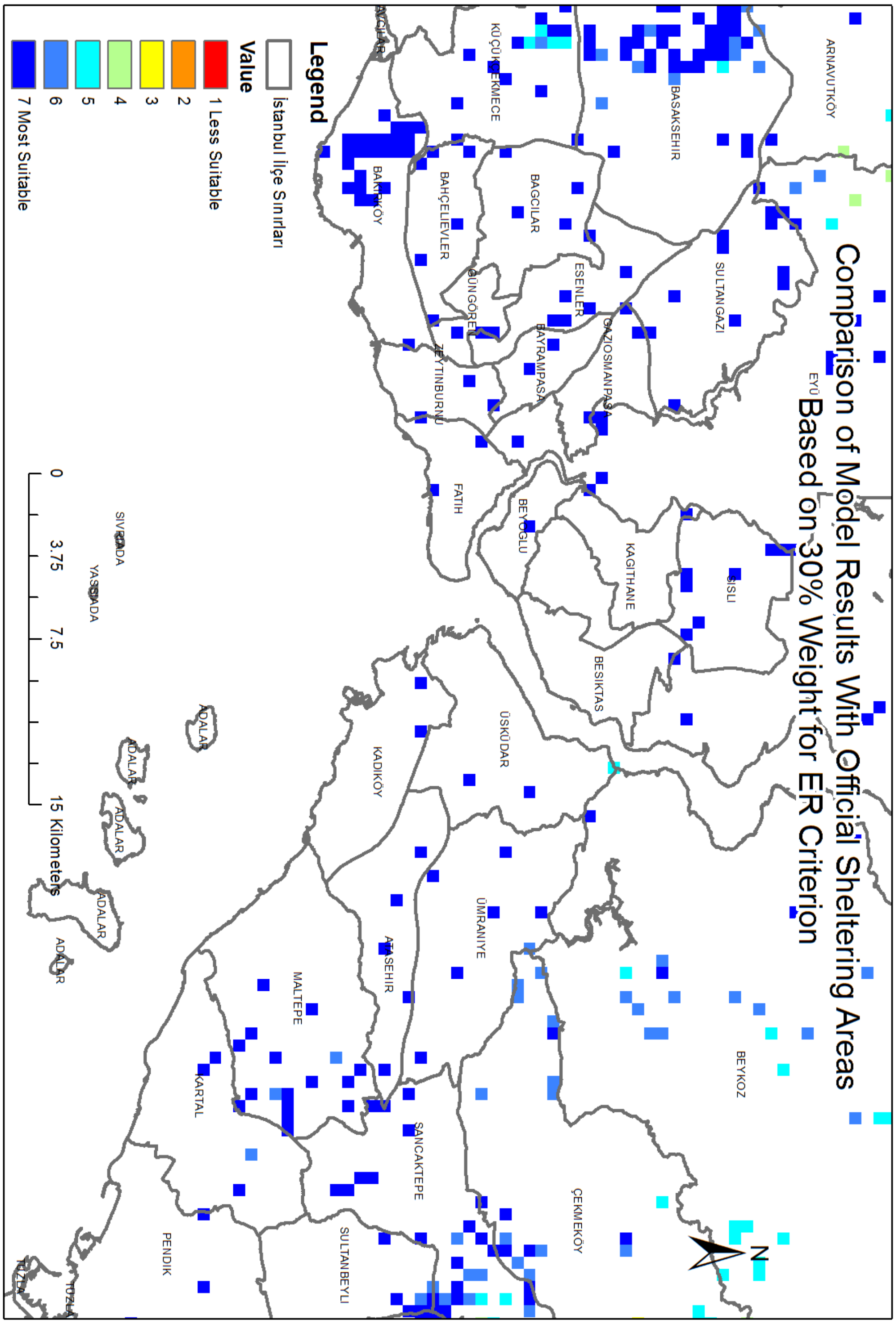

Figure A.27 : Comparison of model results with official sheltering areas based on 30% weight for ER criterion

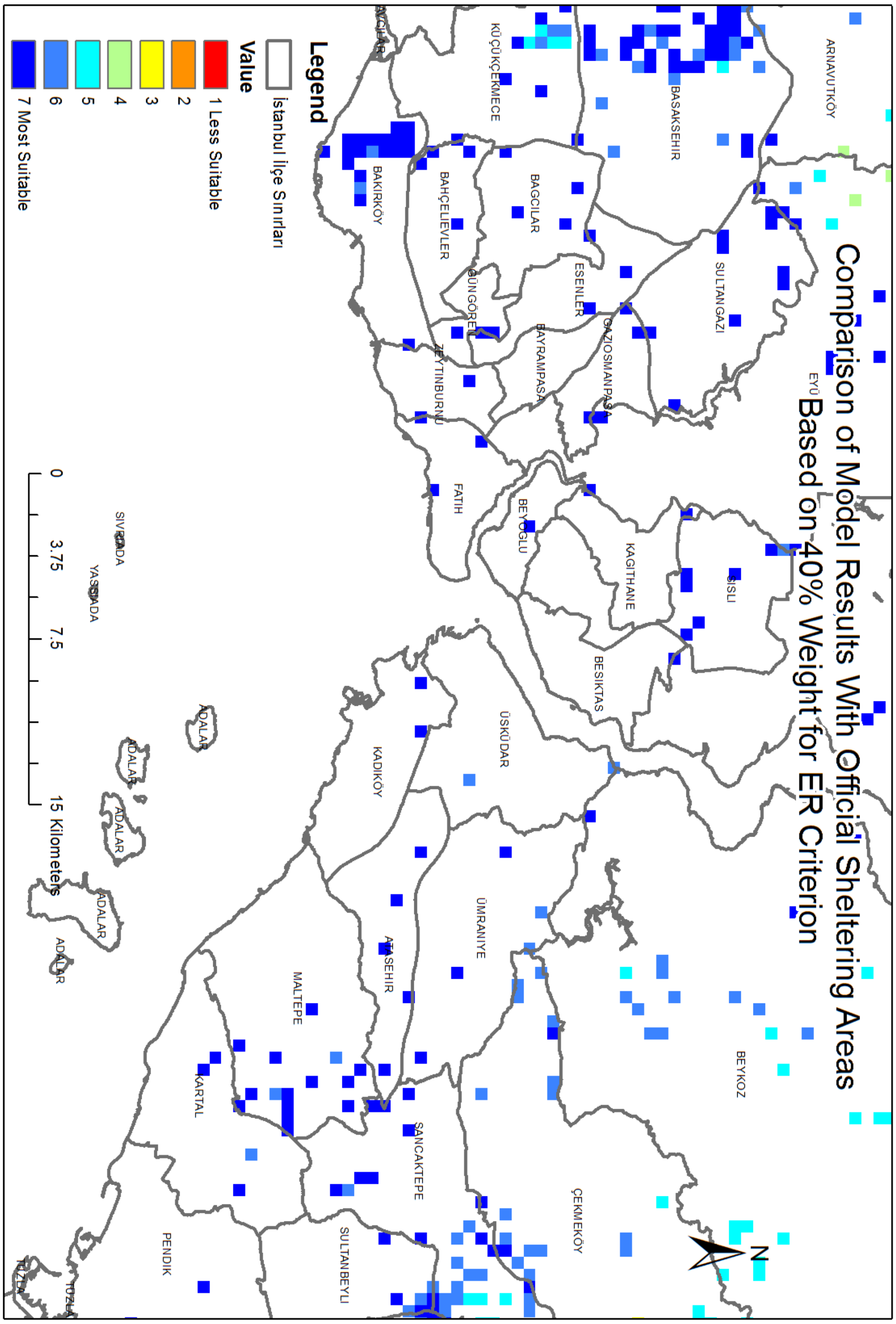

Figure A.28 : Comparison of model results with official sheltering areas based on 40% weight for ER criterion

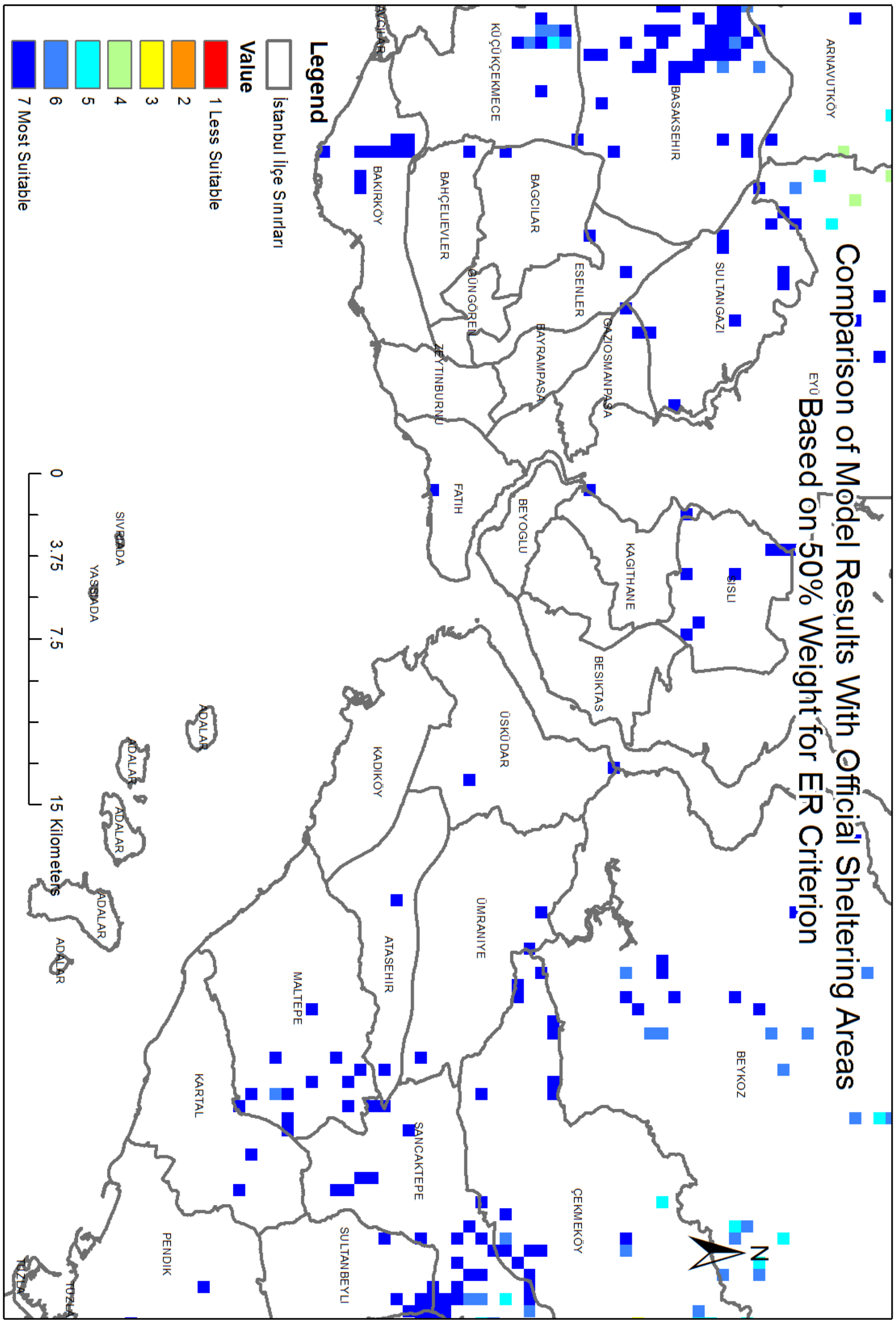

Figure A.29 : Comparison of model results with official sheltering areas based on 50% weight for ER criterion

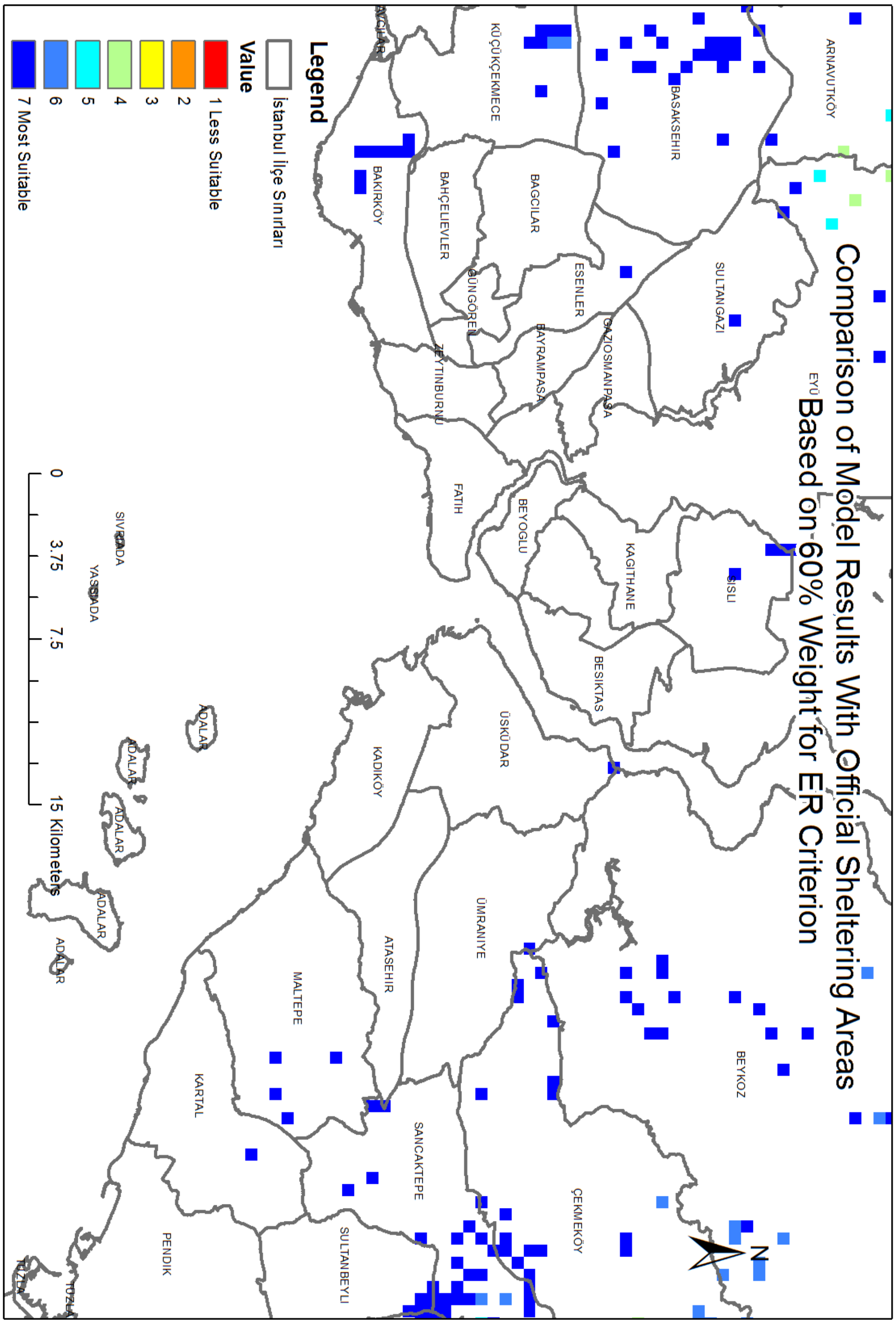

Figure A.30 : Comparison of model results with official sheltering areas based on 60% weight for ER criterion

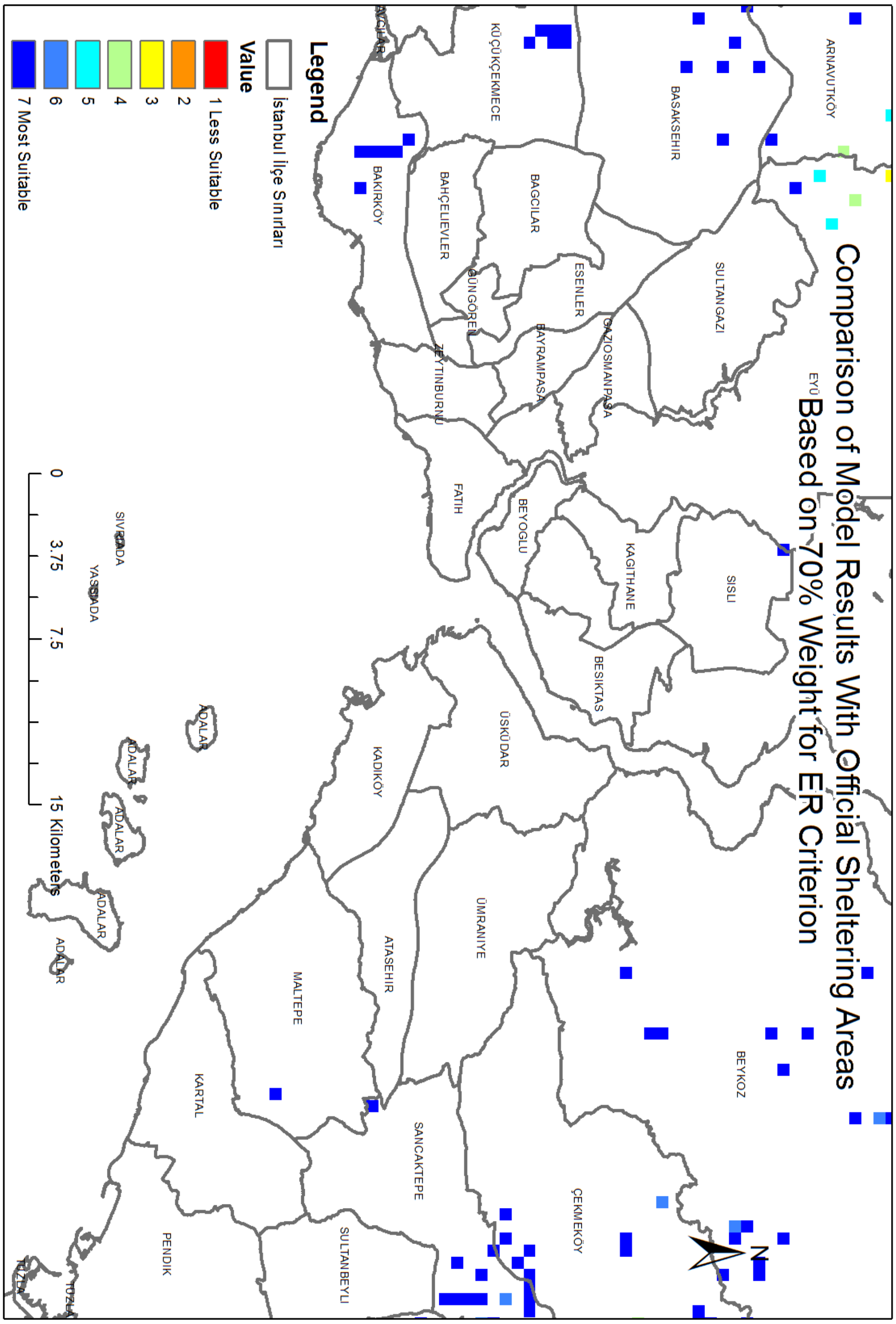

Figure A.31 : Comparison of model results with official sheltering areas based on 70% weight for ER criterion

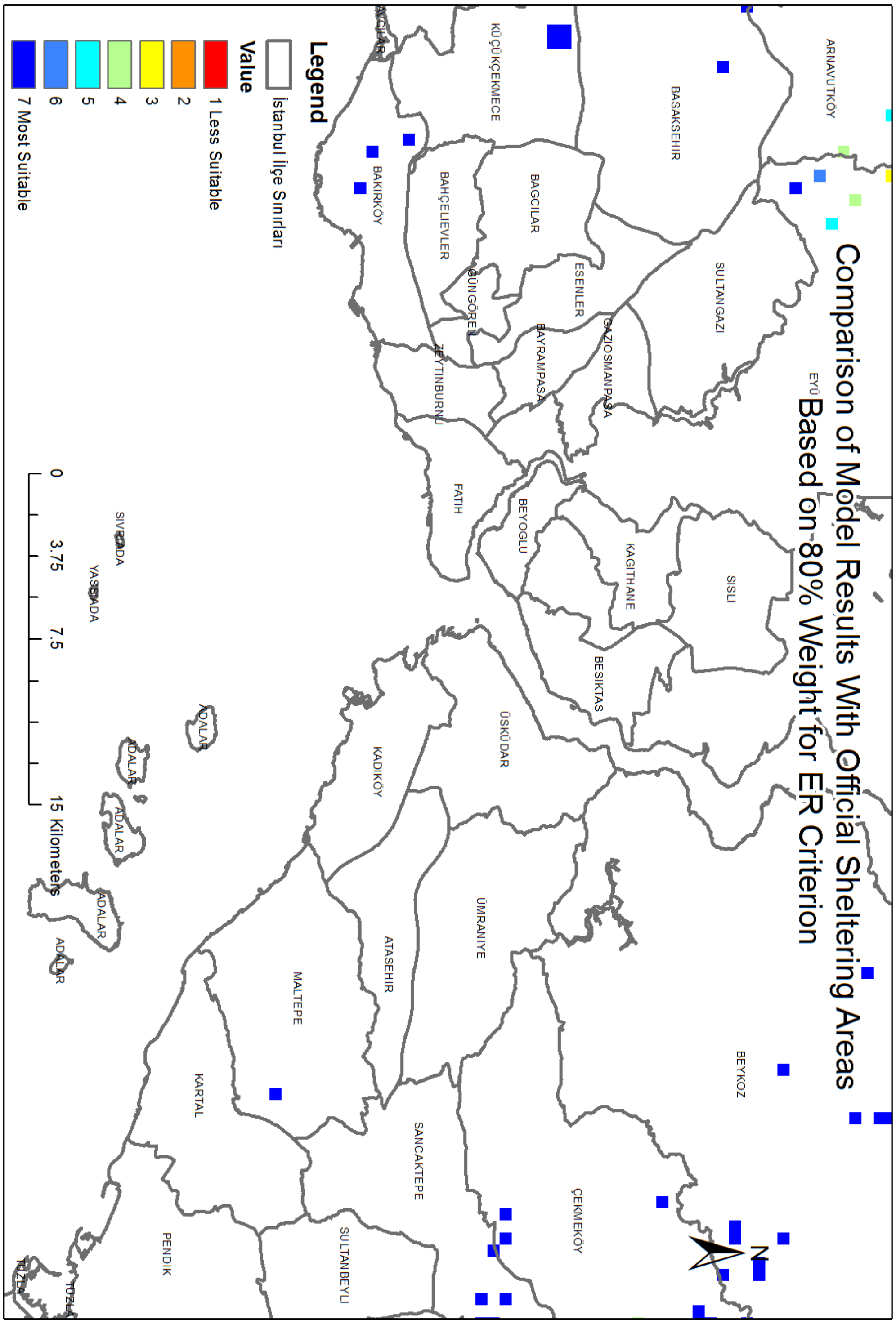

Figure A.32 : Comparison of model results with official sheltering areas based on 80% weight for ER criterion

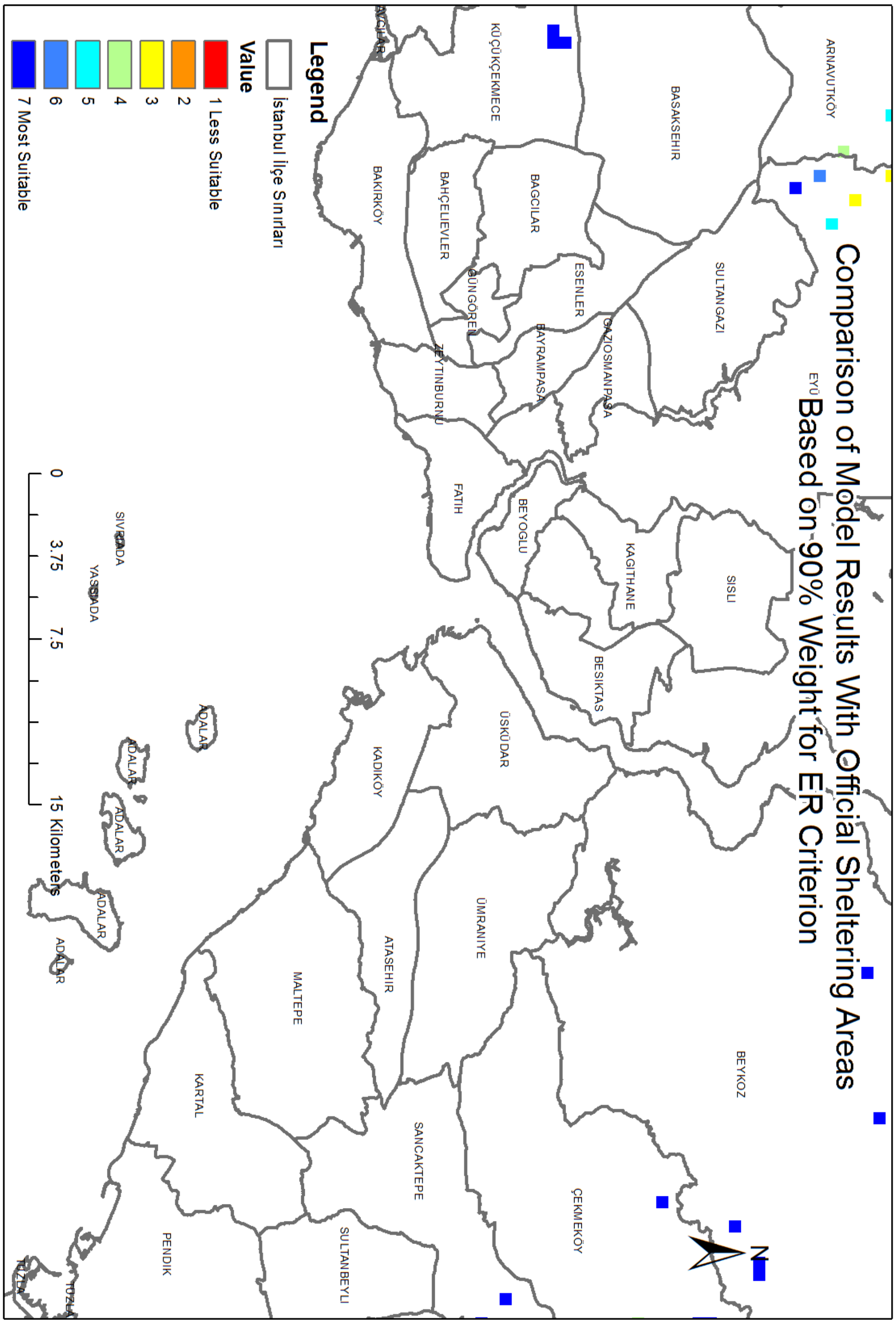

Figure A.33 : Comparison of model results with official sheltering areas based on 90% weight for ER criterion

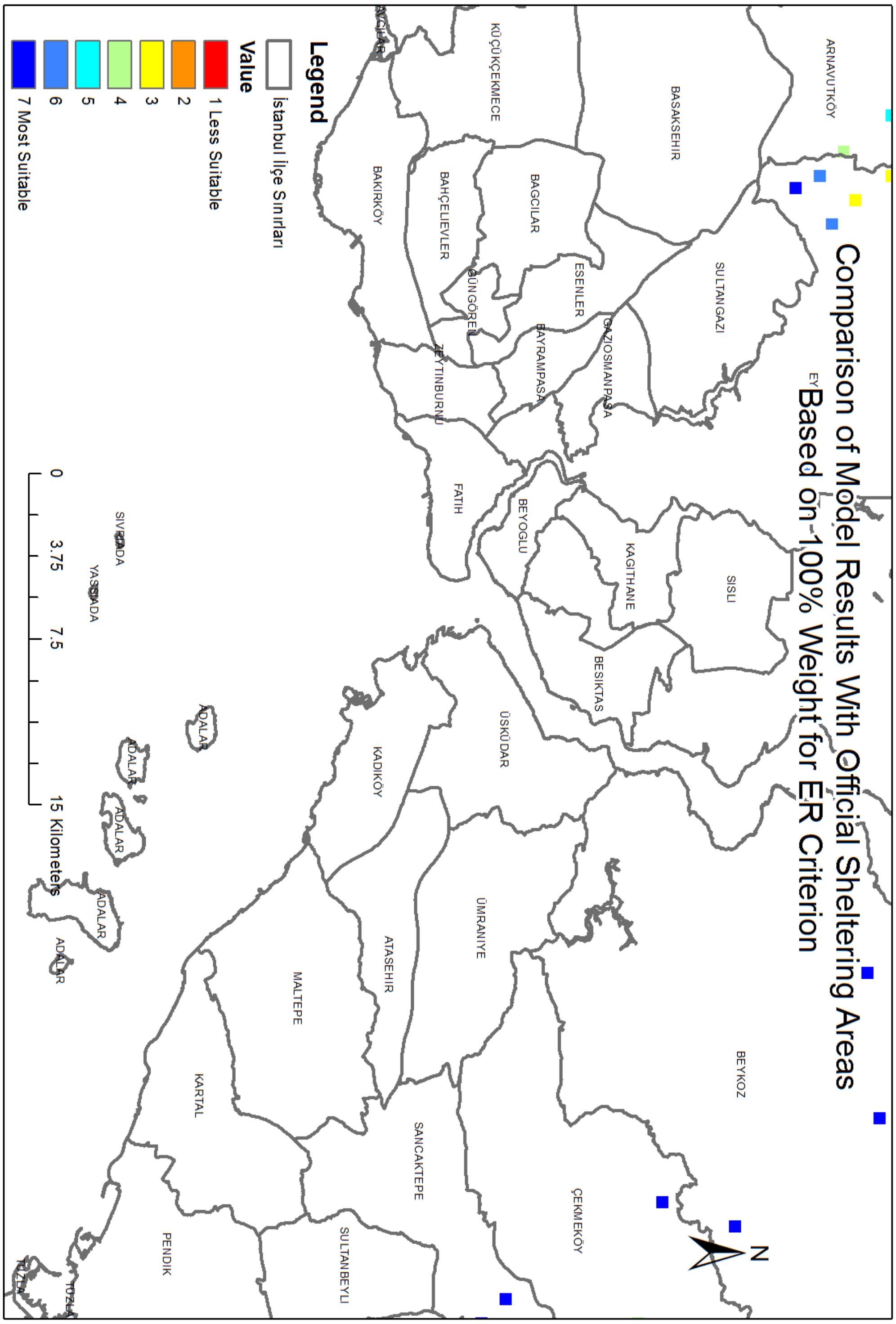

Figure A.34 : Comparison of model results with official sheltering areas based on 100% weight for ER criterion

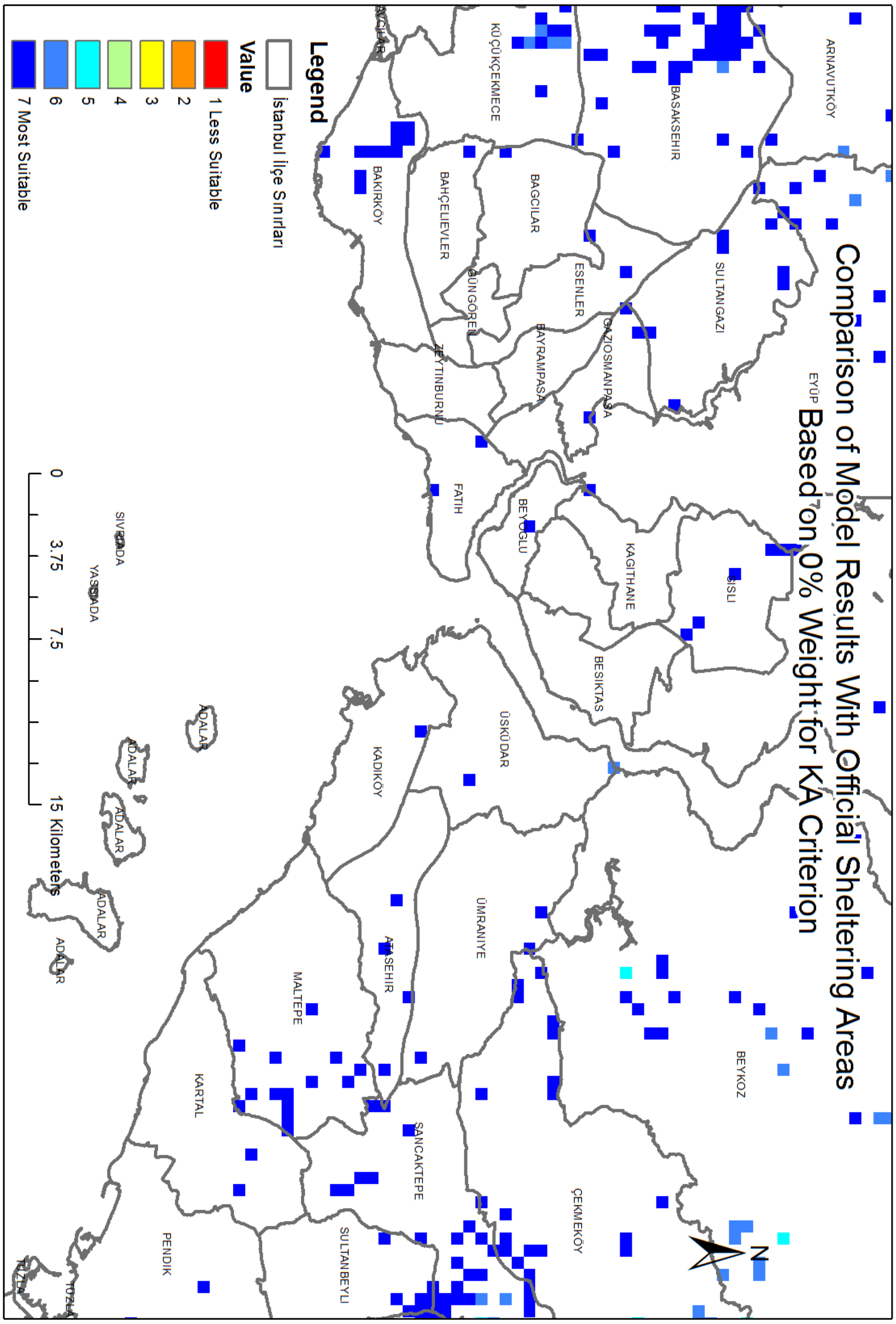

Figure A.35 : Comparison of model results with official sheltering areas based on 0% weight for KA criterion

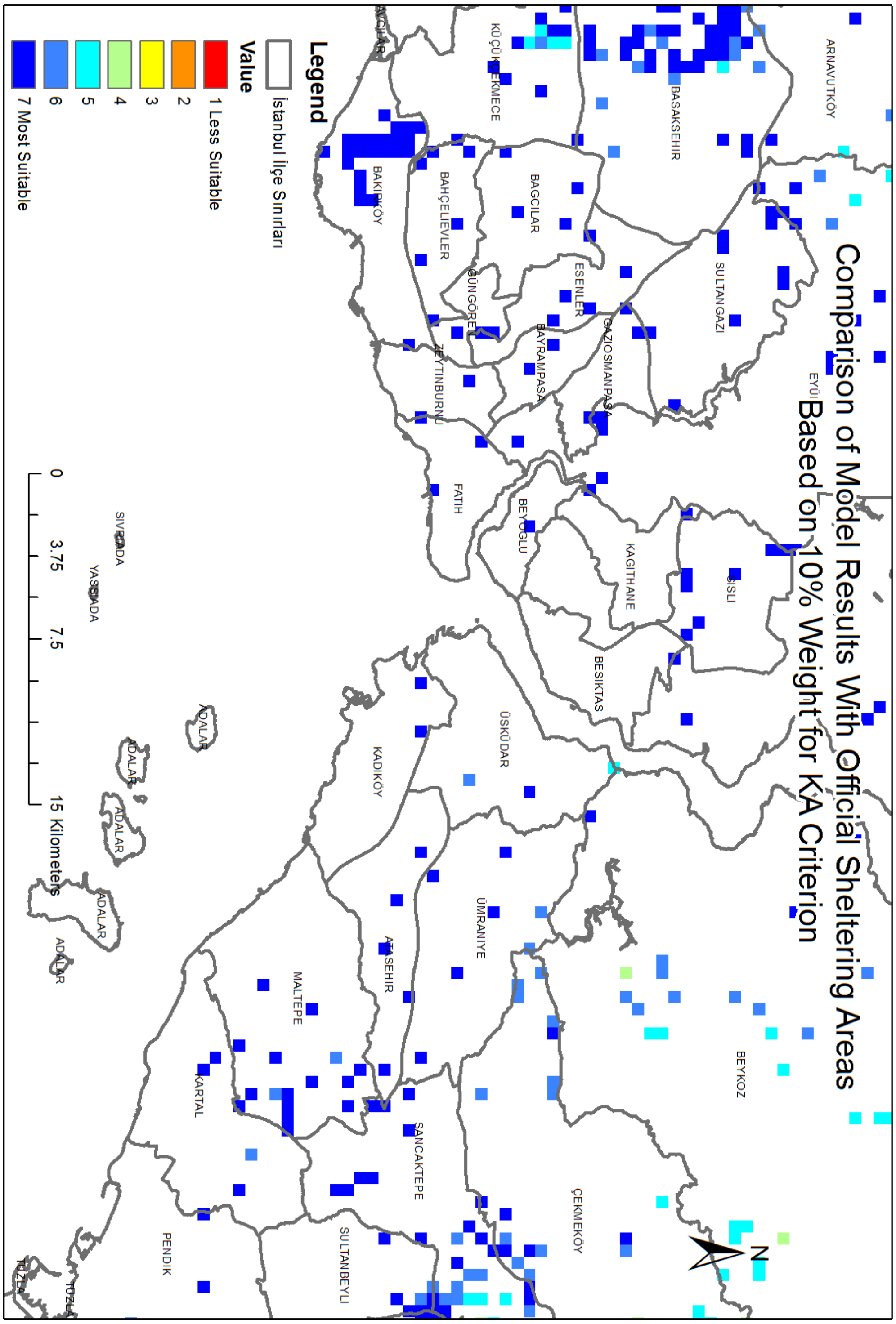

Figure A.36 : Comparison of model results with official sheltering areas based on 10% weight for KA criterion

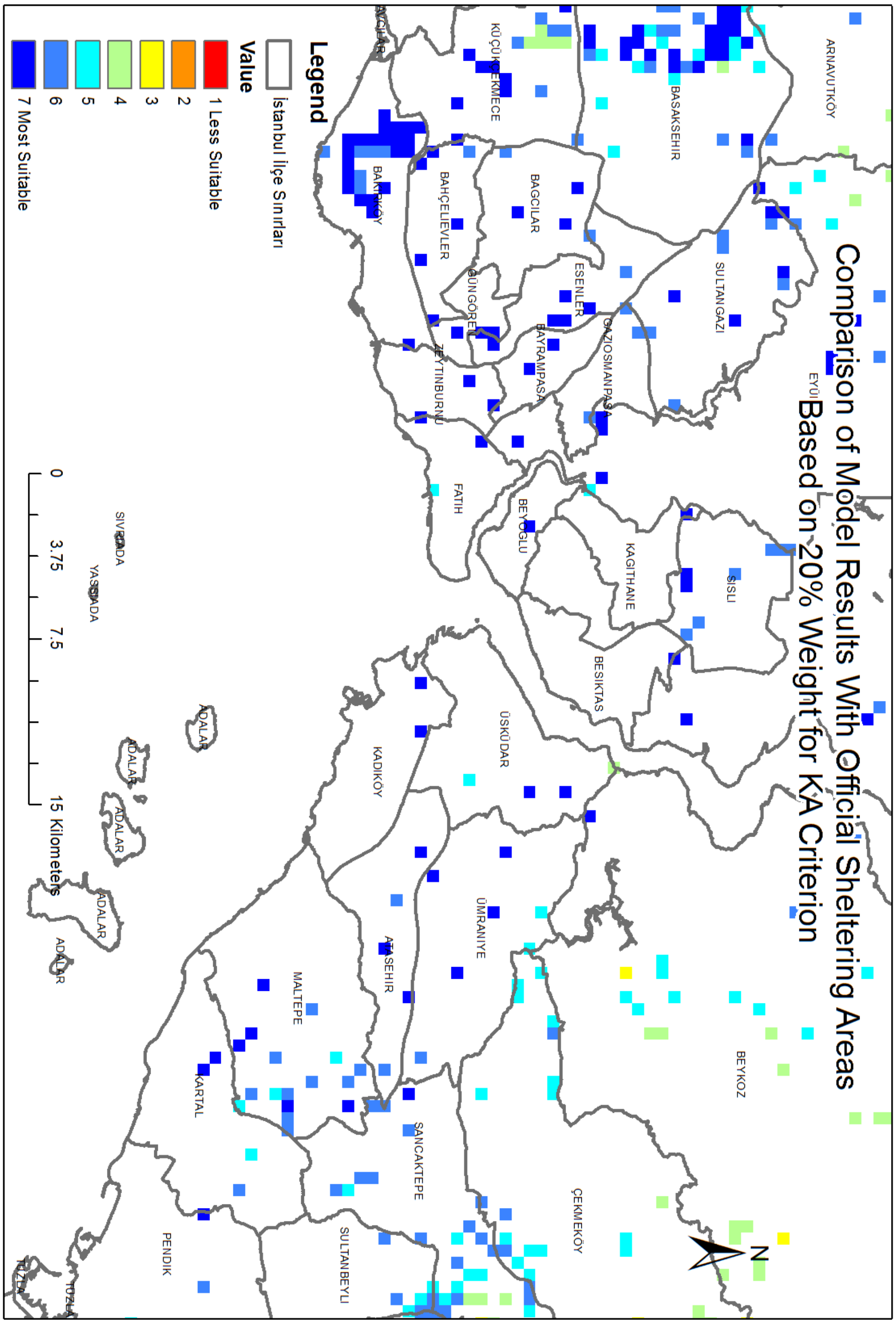

Figure A.37 : Comparison of model results with official sheltering areas based on 20% weight for KA criterion

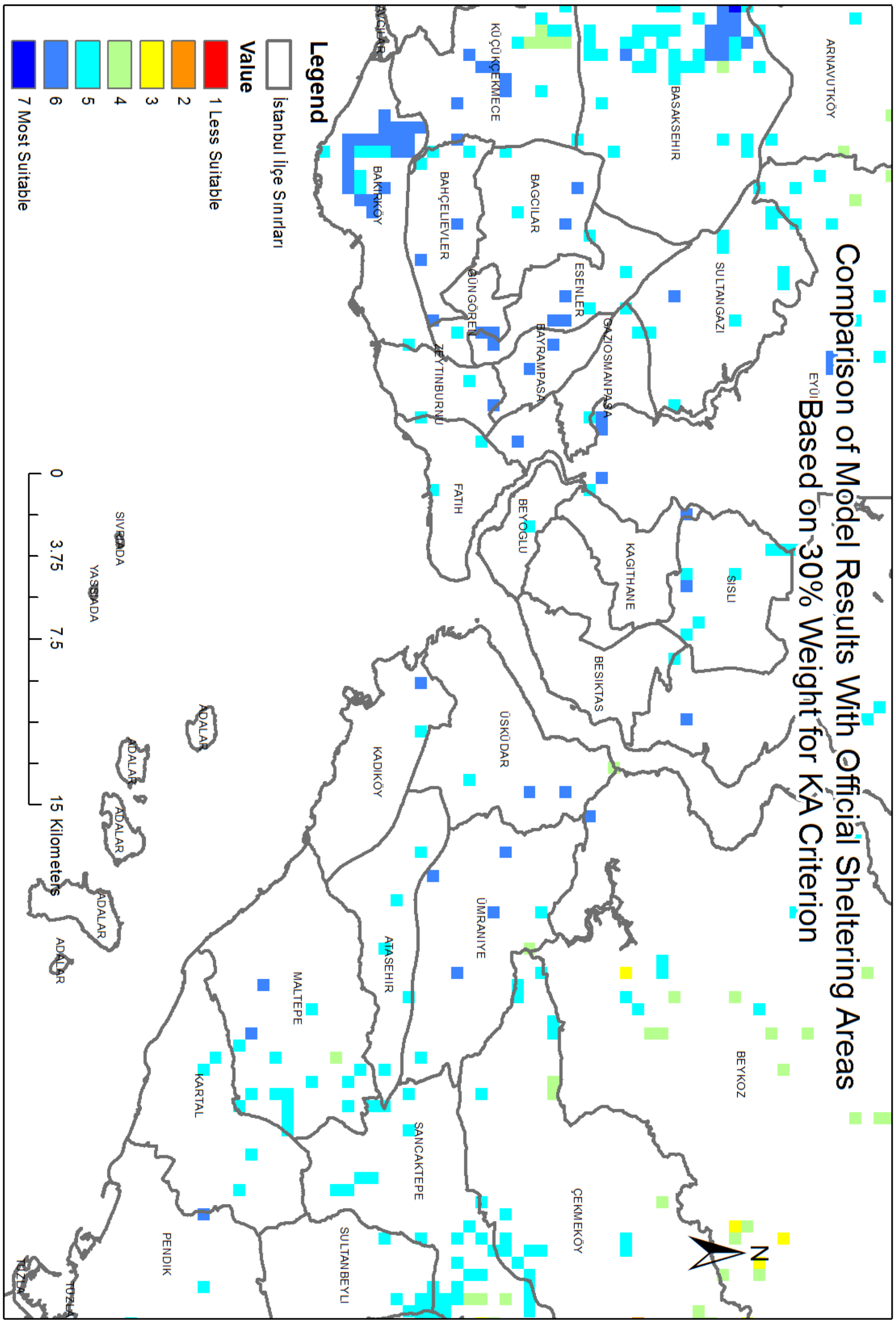

Figure A.38 : Comparison of model results with official sheltering areas based on 30% weight for KA criterion

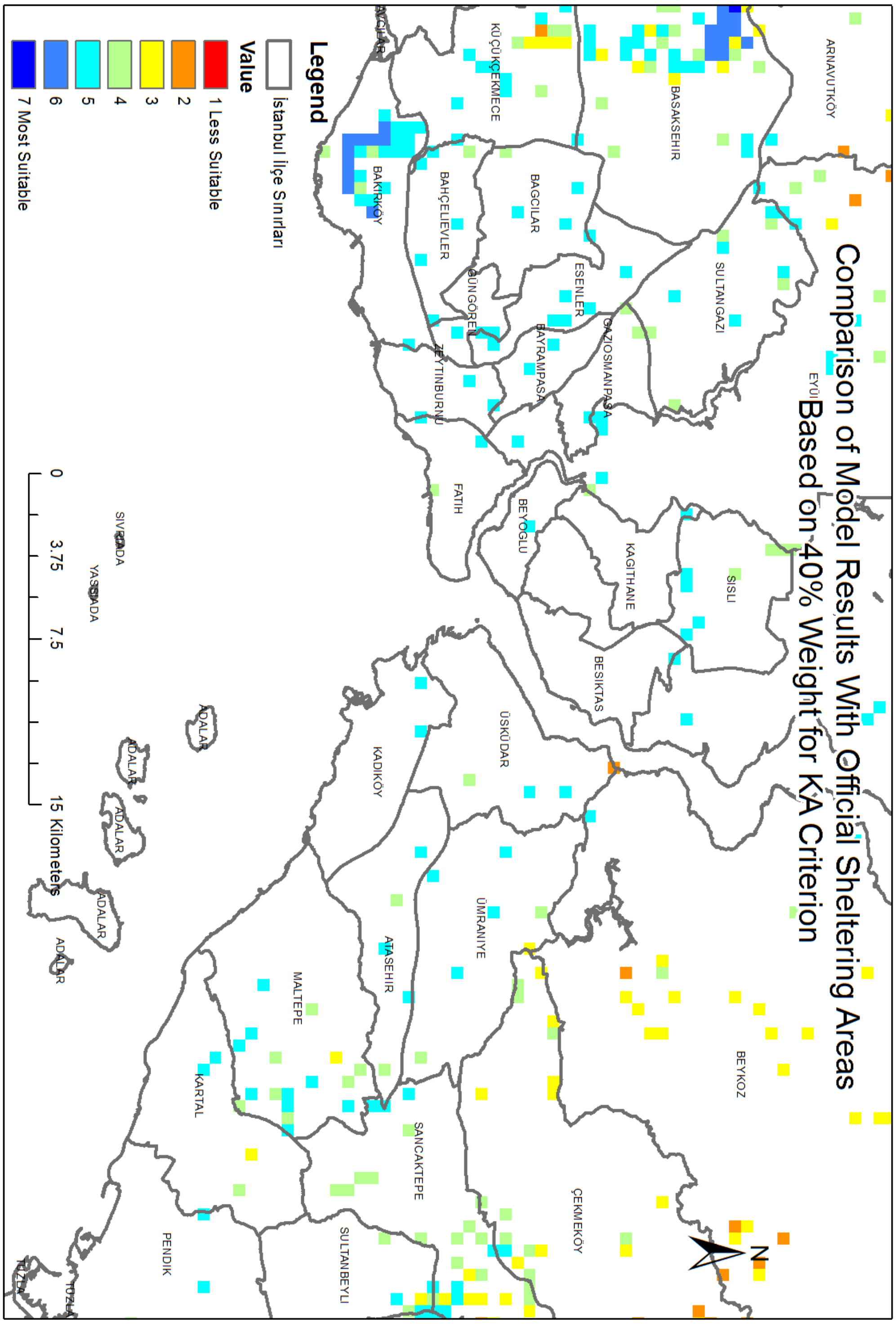

Figure A.39 : Comparison of model results with official sheltering areas based on 40% weight for KA criterion

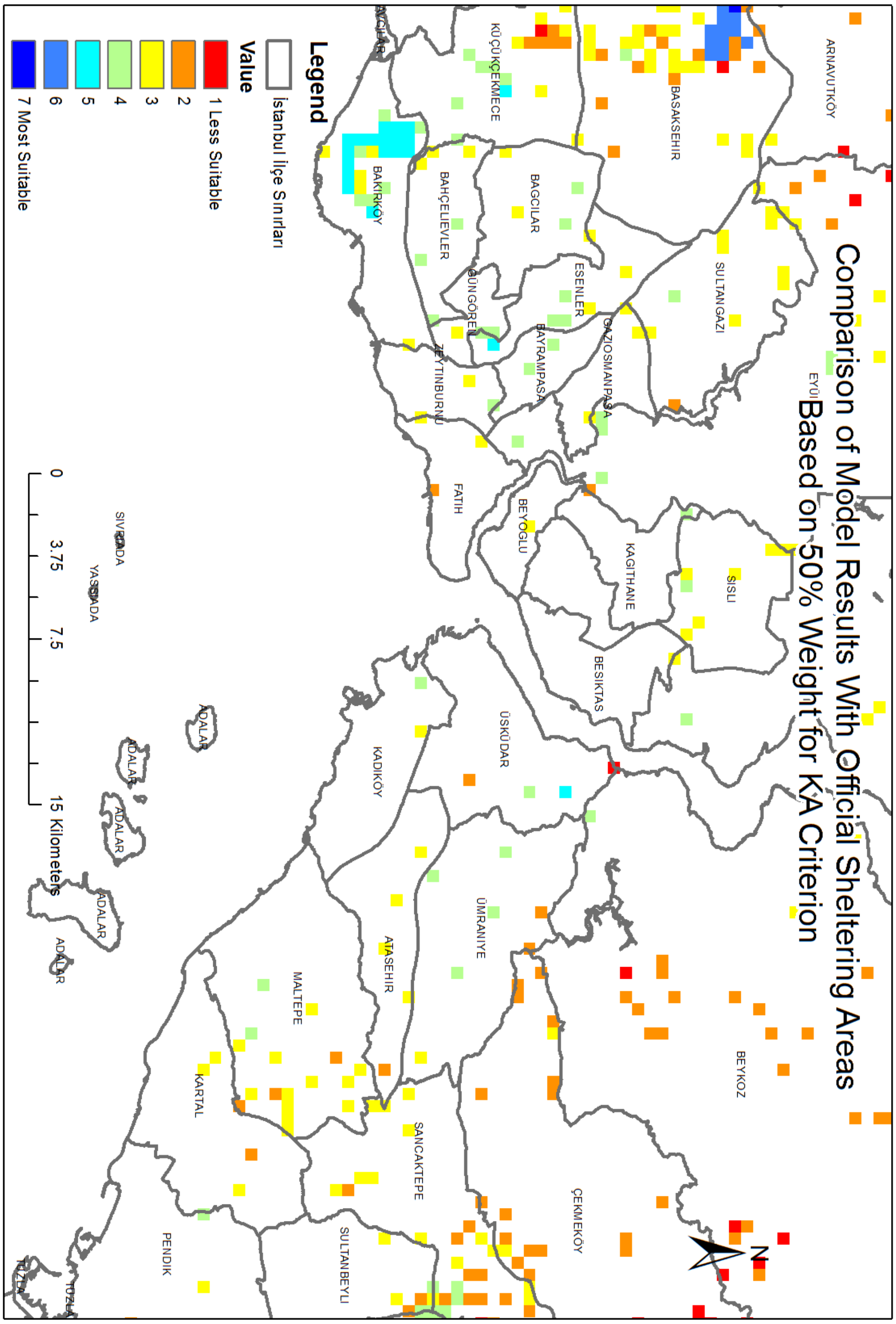

Figure A.40 : Comparison of model results with official sheltering areas based on 50% weight for KA criterion

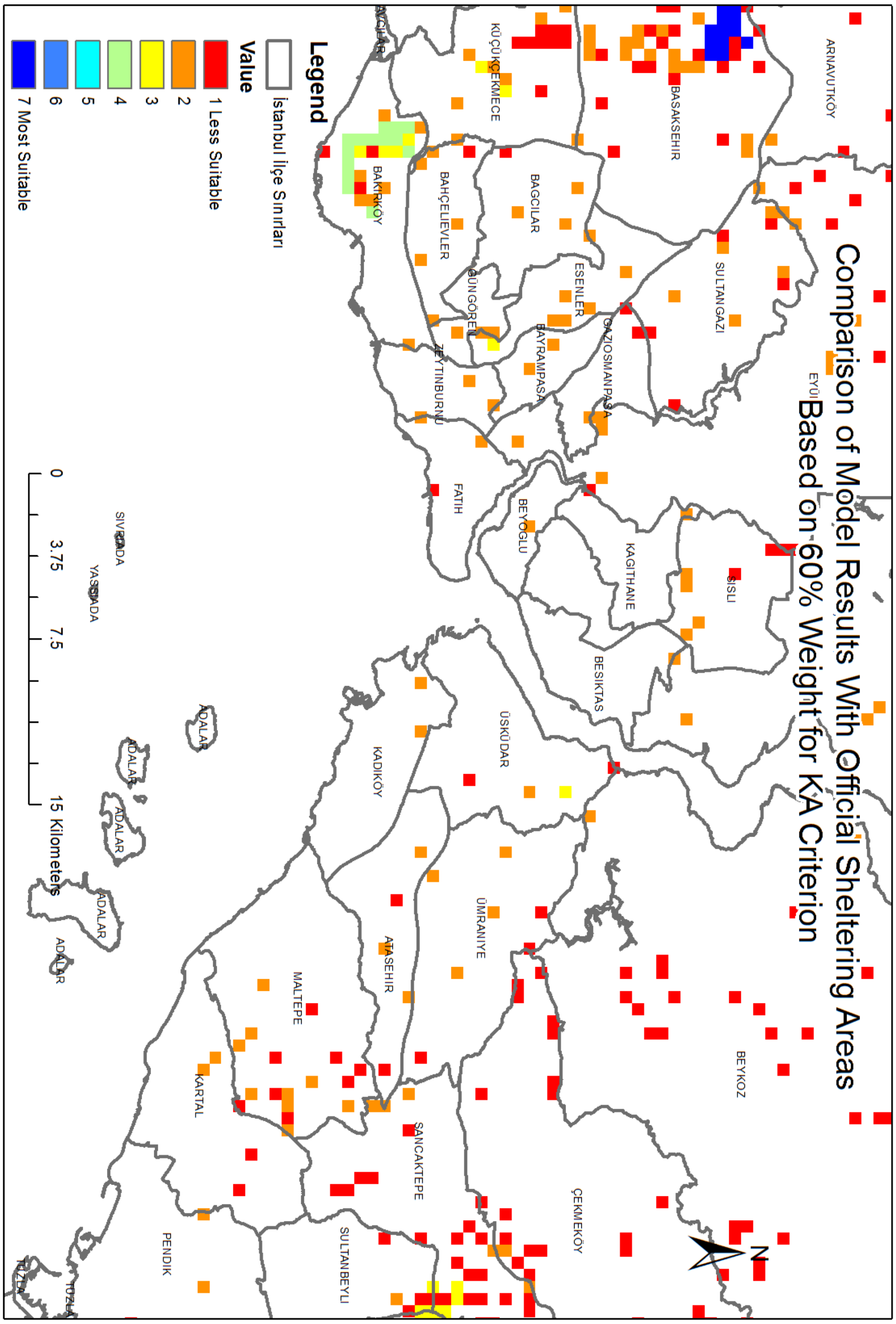

Figure A.41 : Comparison of model results with official sheltering areas based on 60% weight for KA criterion

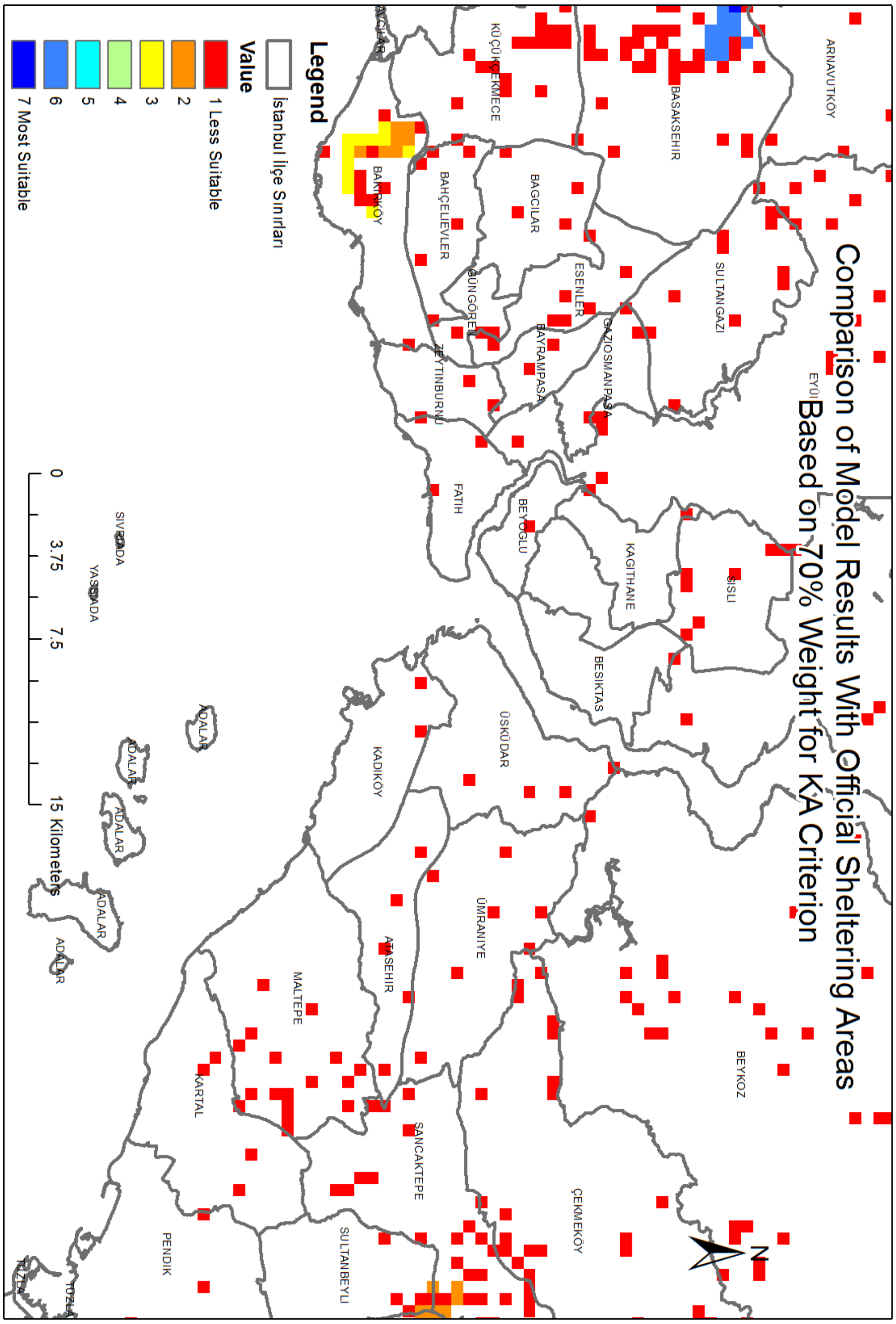

Figure A.42 : Comparison of model results with official sheltering areas based on 70% weight for KA criterion

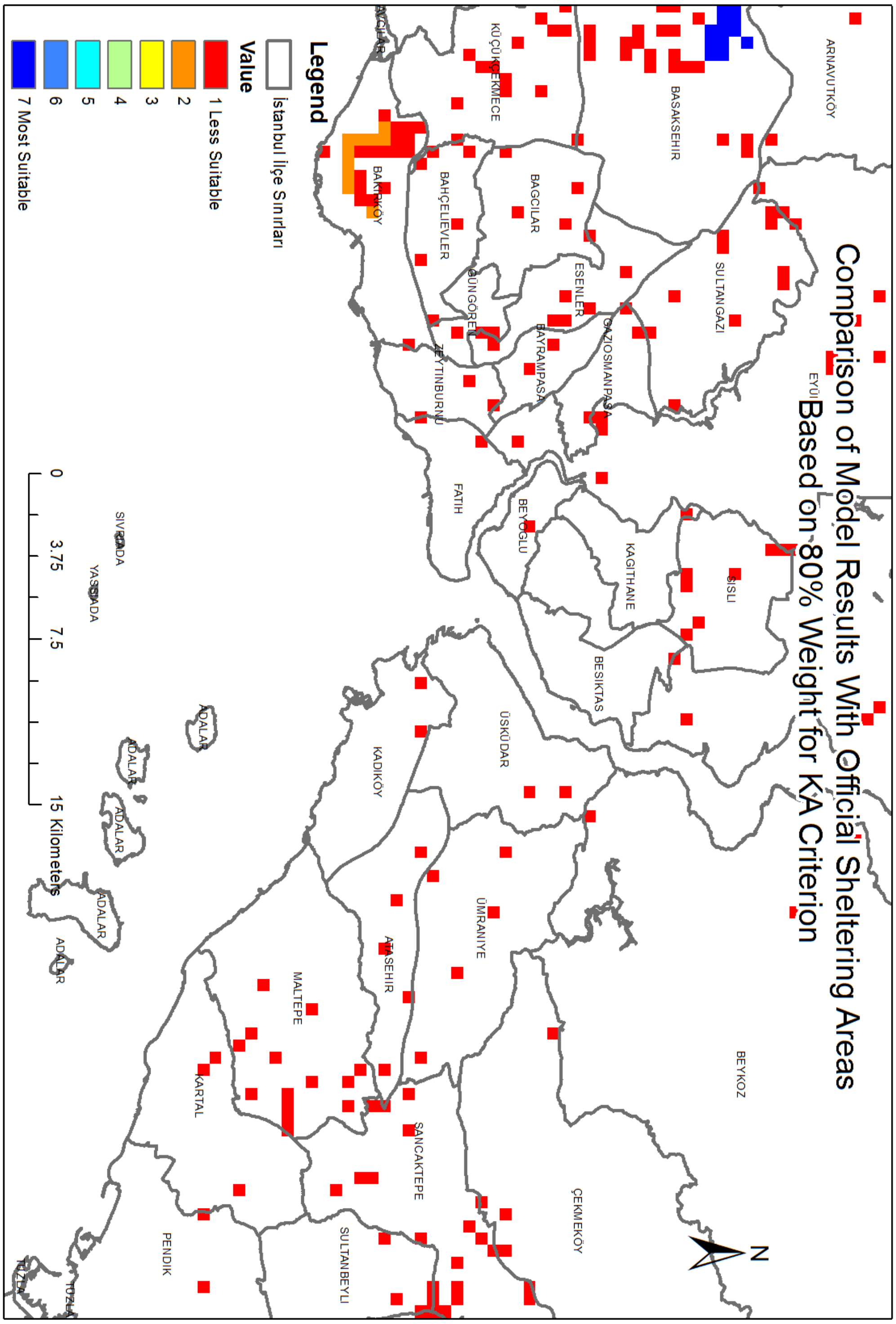

Figure A.43 : Comparison of model results with official sheltering areas based on 80% weight for KA criterion

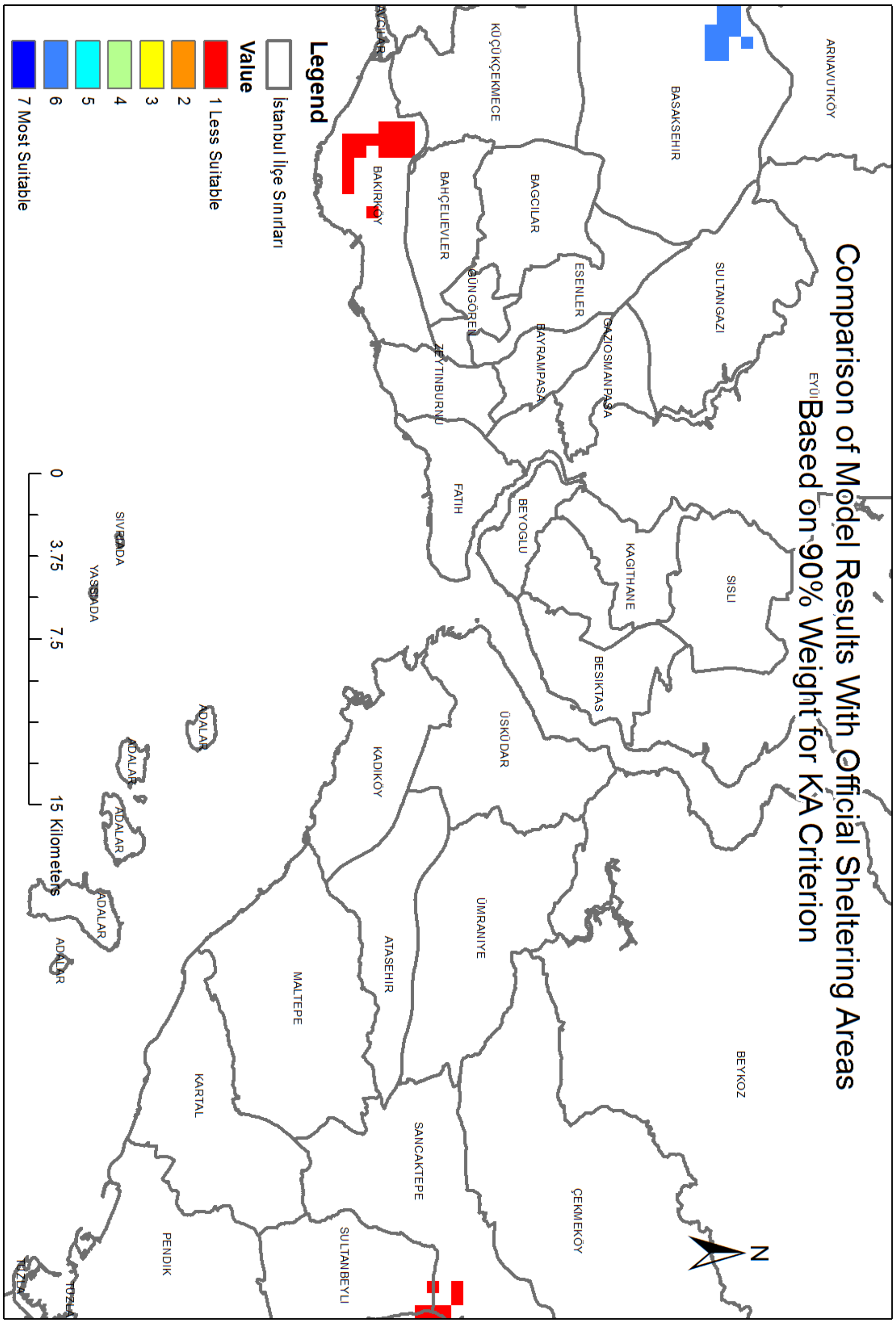

Figure A.44 : Comparison of model results with official sheltering areas based on 90% weight for KA criterion

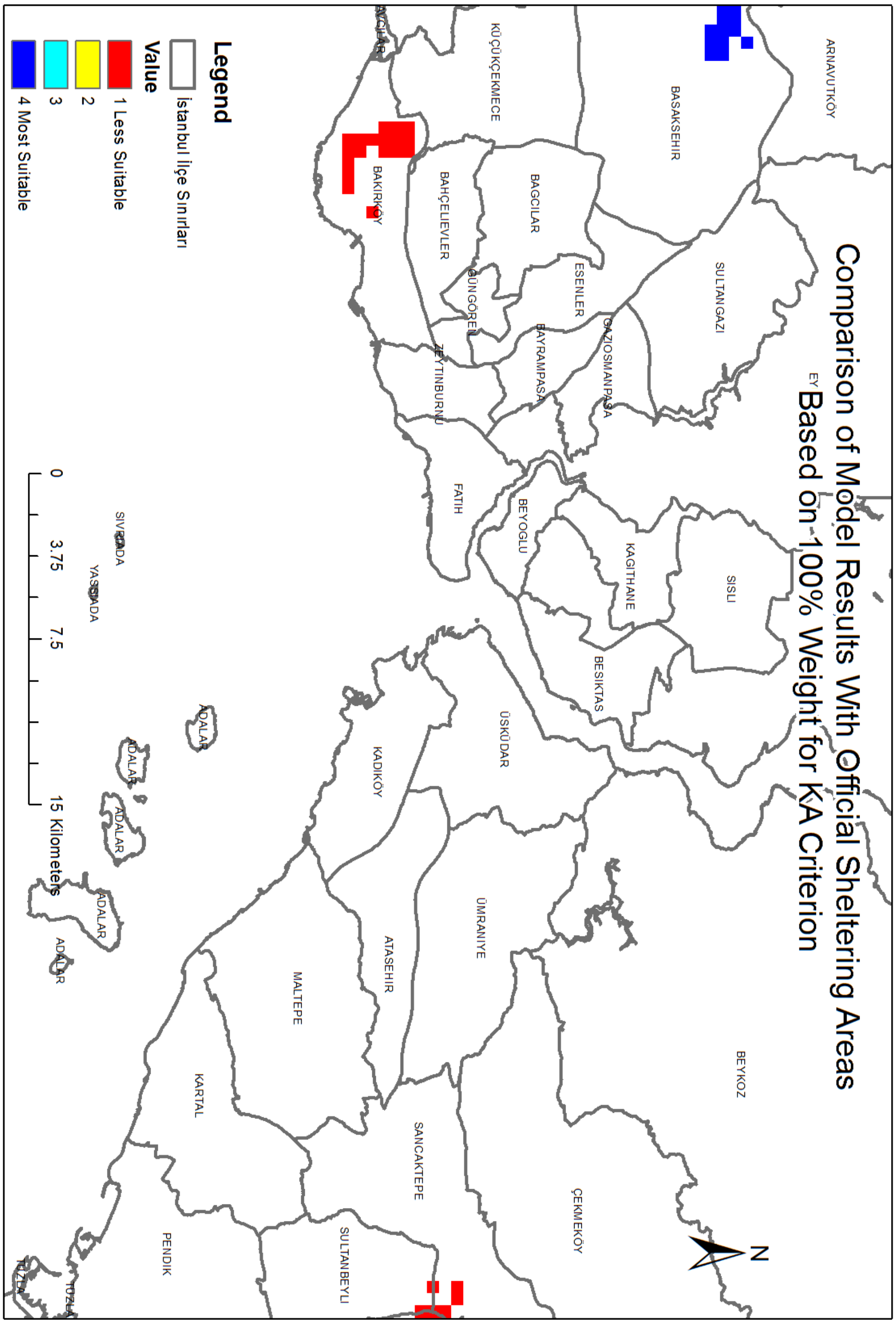

Figure A.45 : Comparison of model results with official sheltering areas based on 100% weight for KA criterion

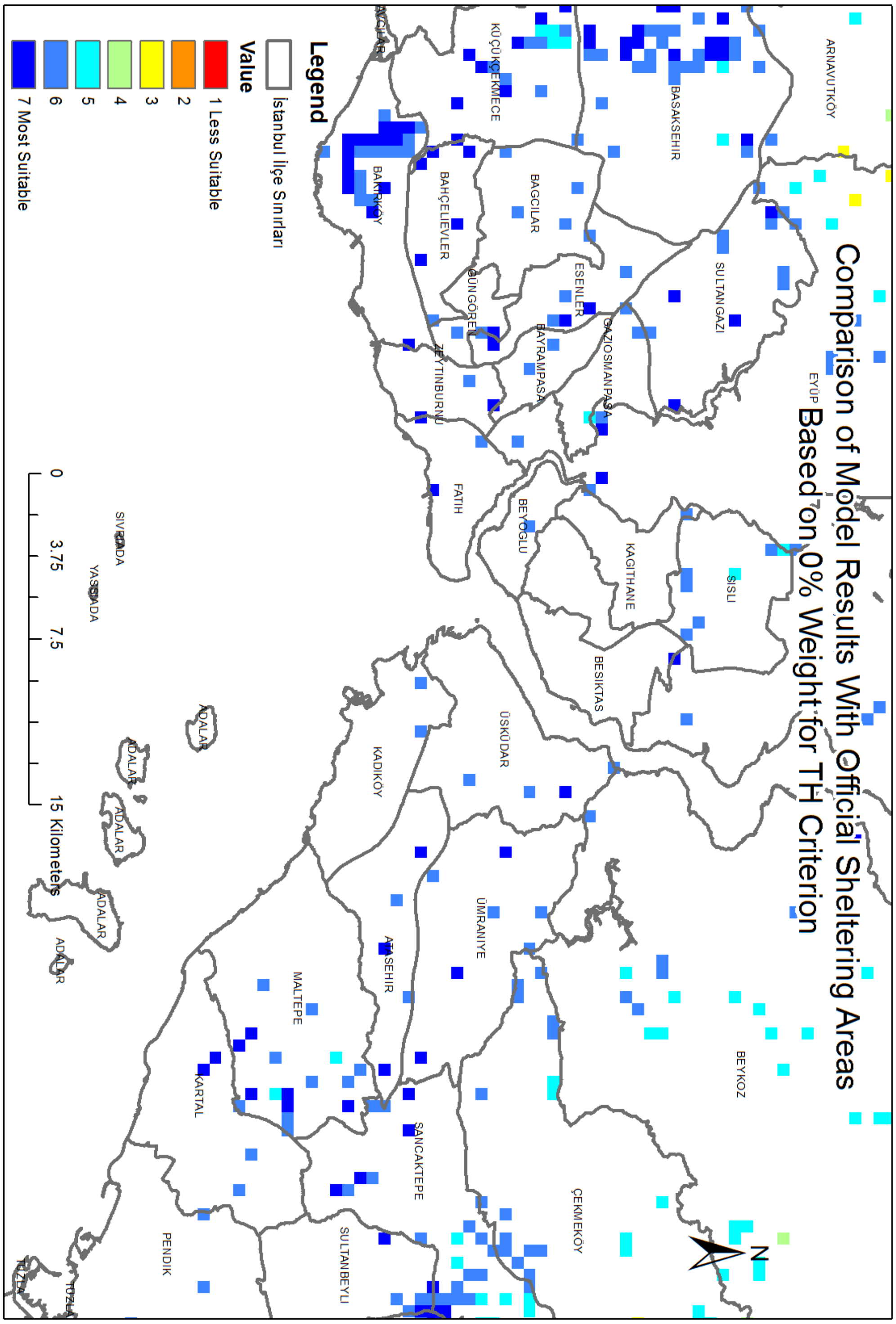

Figure A.46 : Comparison of model results with official sheltering areas based on 0% weight for TH criterion

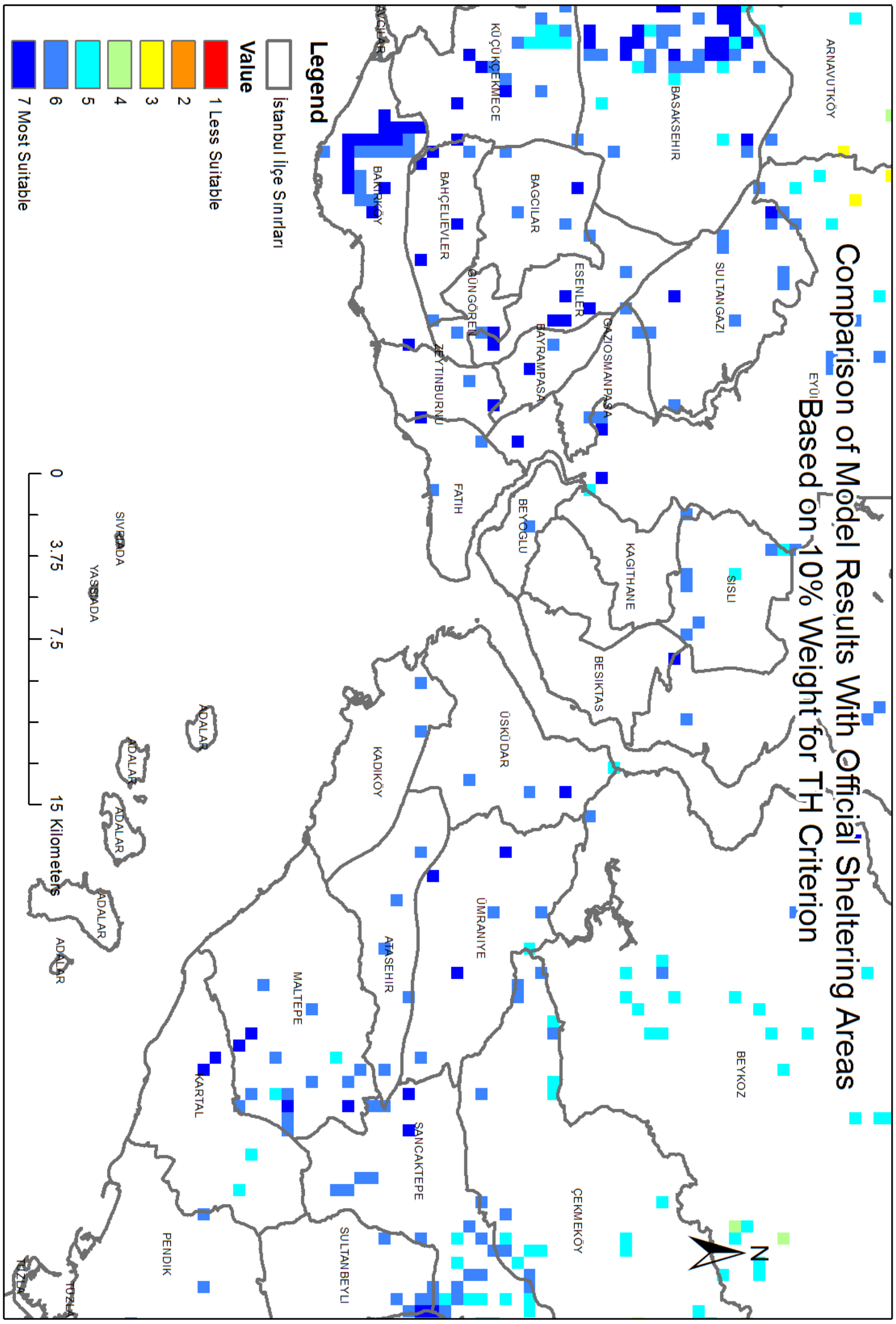

Figure A.47 : Comparison of model results with official sheltering areas based on 10% weight for TH criterion

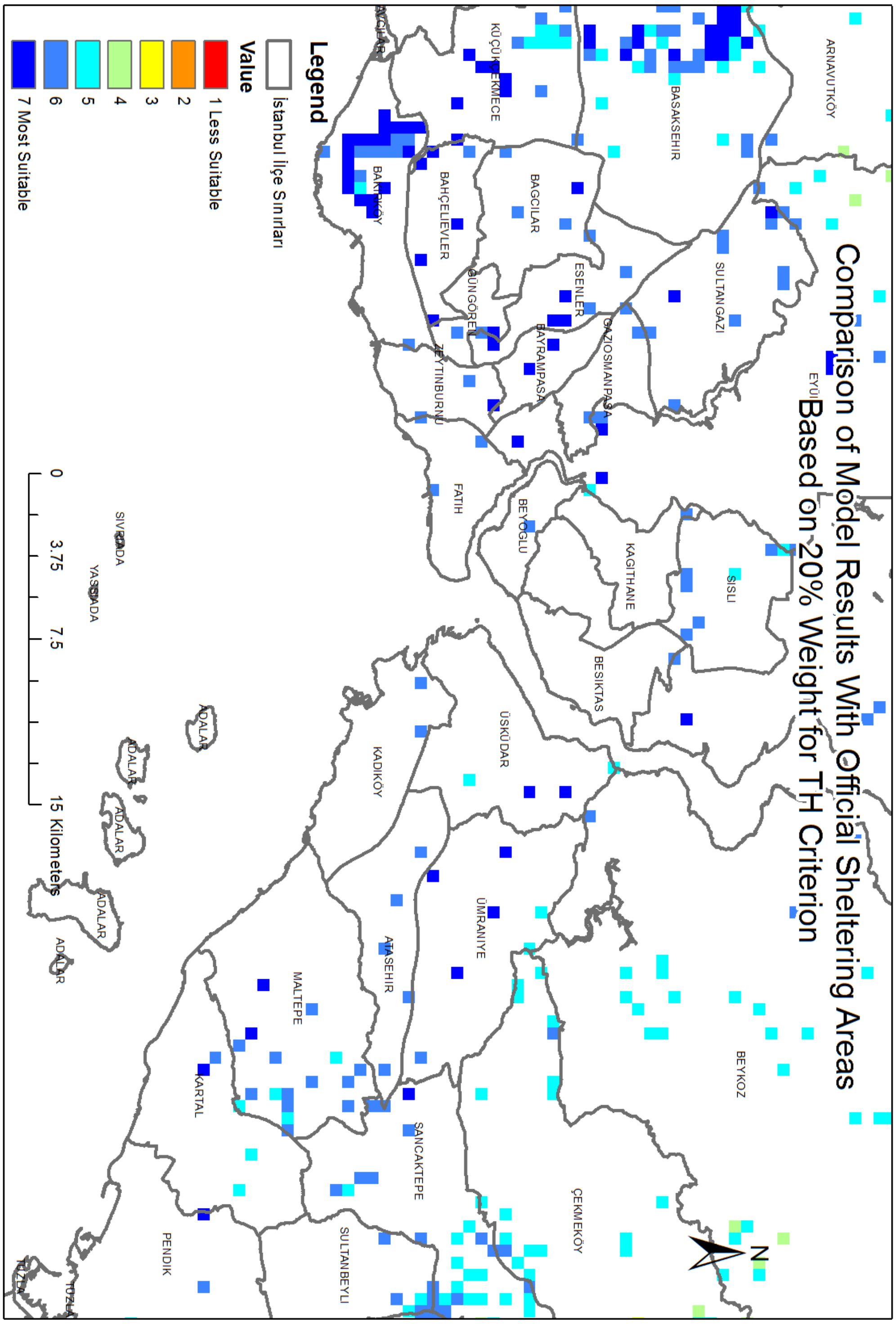

Figure A.48 : Comparison of model results with official sheltering areas based on 20% weight for TH criterion

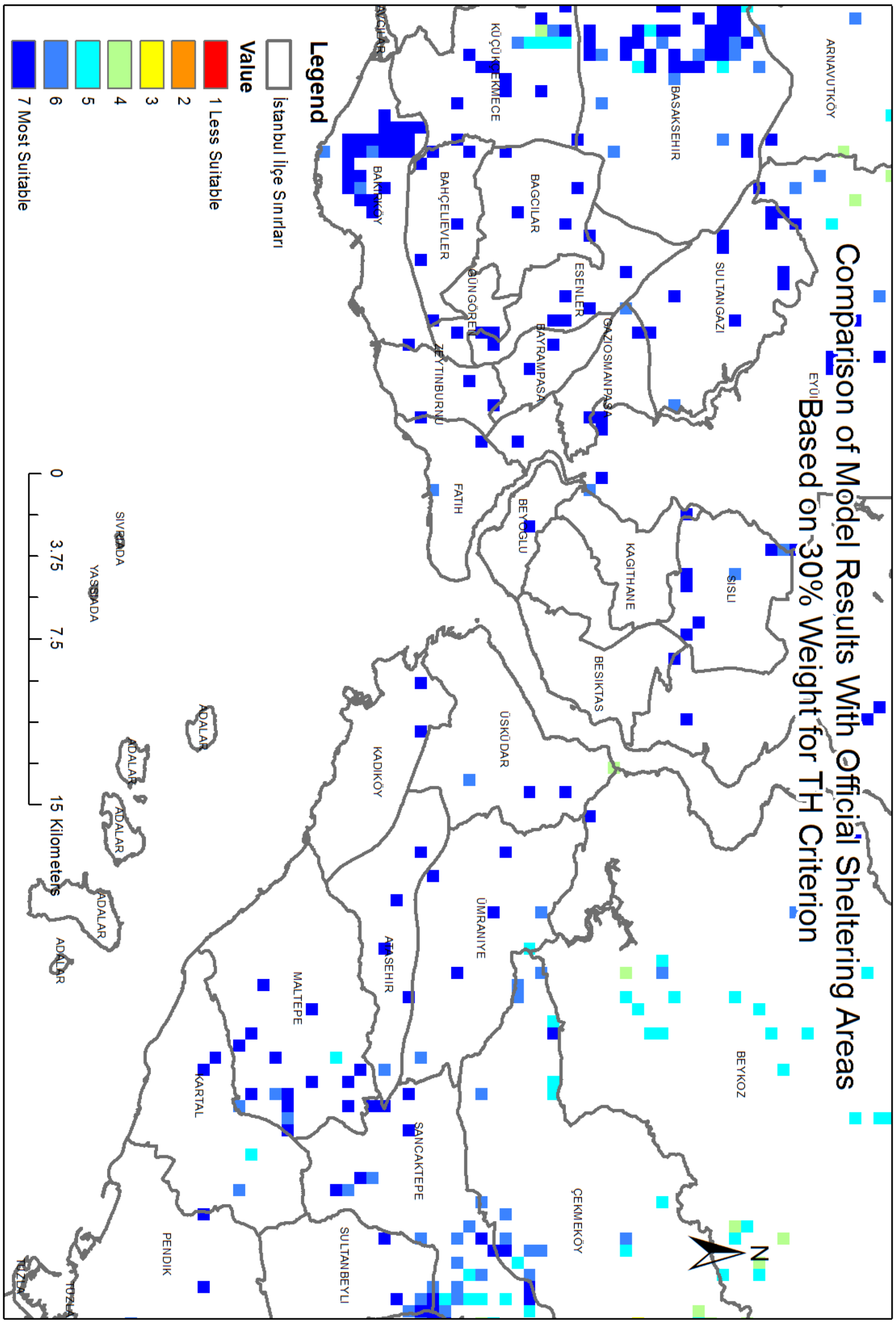

Figure A.49 : Comparison of model results with official sheltering areas based on 30% weight for TH criterion

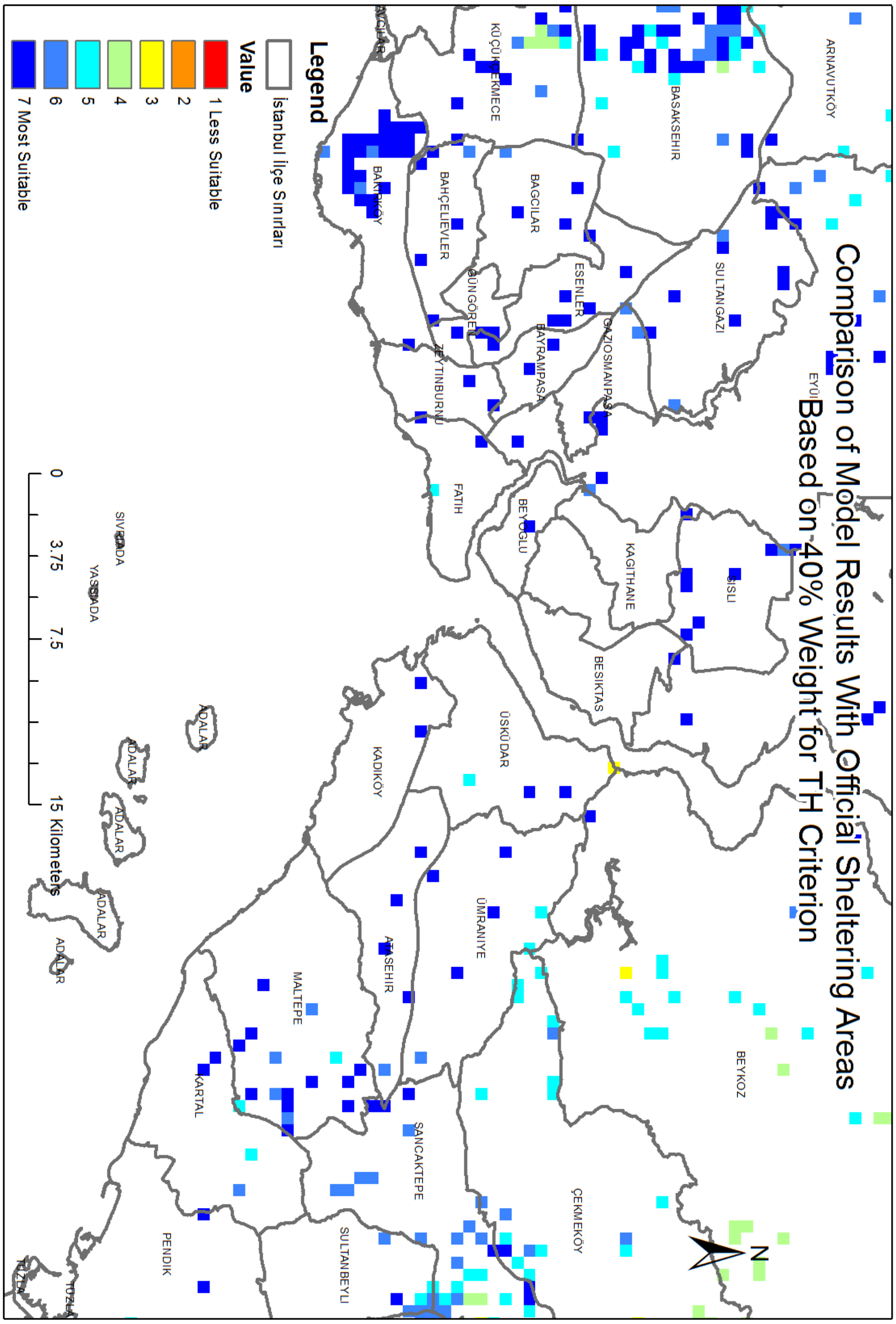

Figure A.50 : Comparison of model results with official sheltering areas based on 40% weight for TH criterion

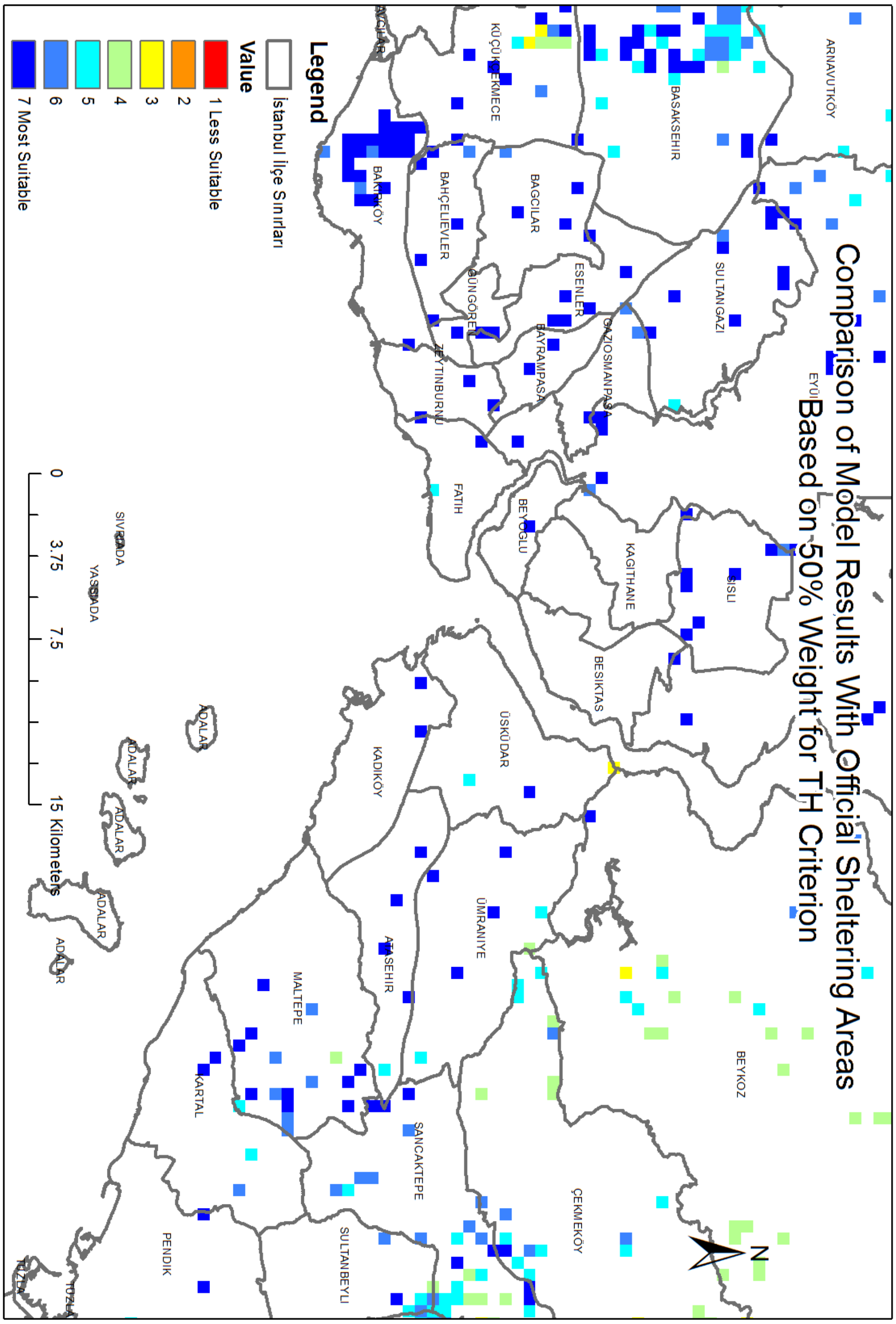

Figure A.51 : Comparison of model results with official sheltering areas based on 50% weight for TH criterion

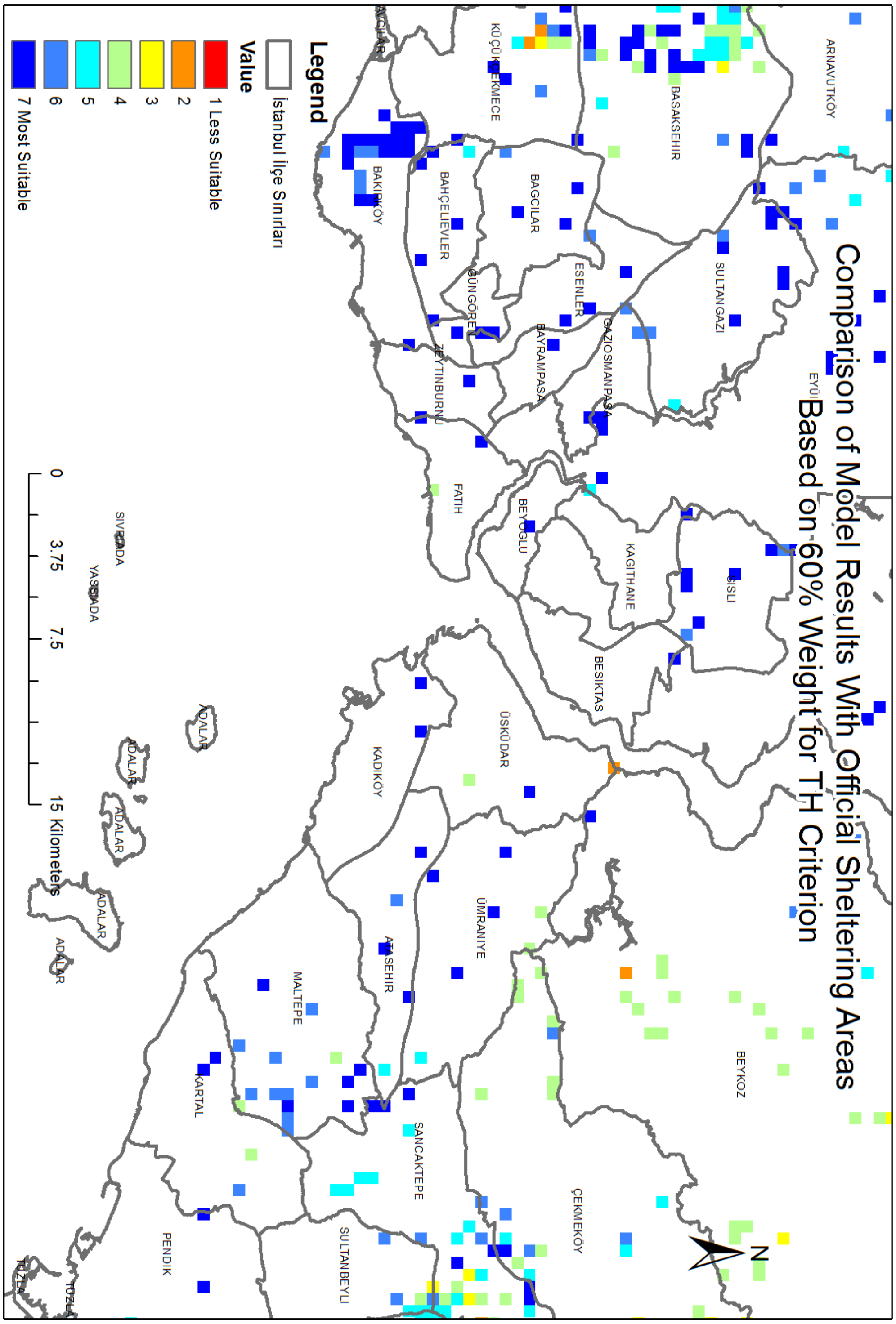

Figure A.52 : Comparison of model results with official sheltering areas based on 60% weight for TH criterion

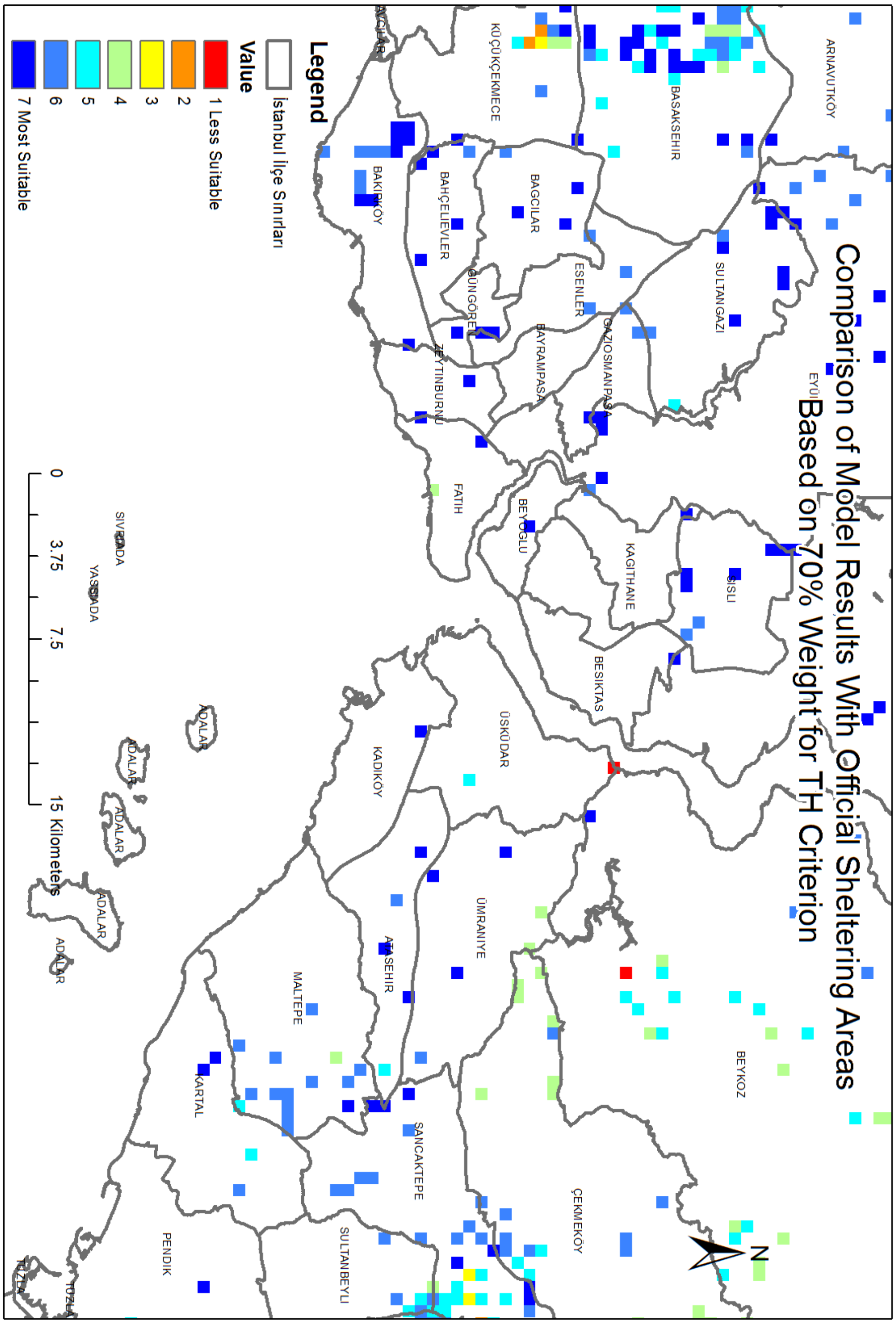

Figure A.53 : Comparison of model results with official sheltering areas based on 70% weight for TH criterion

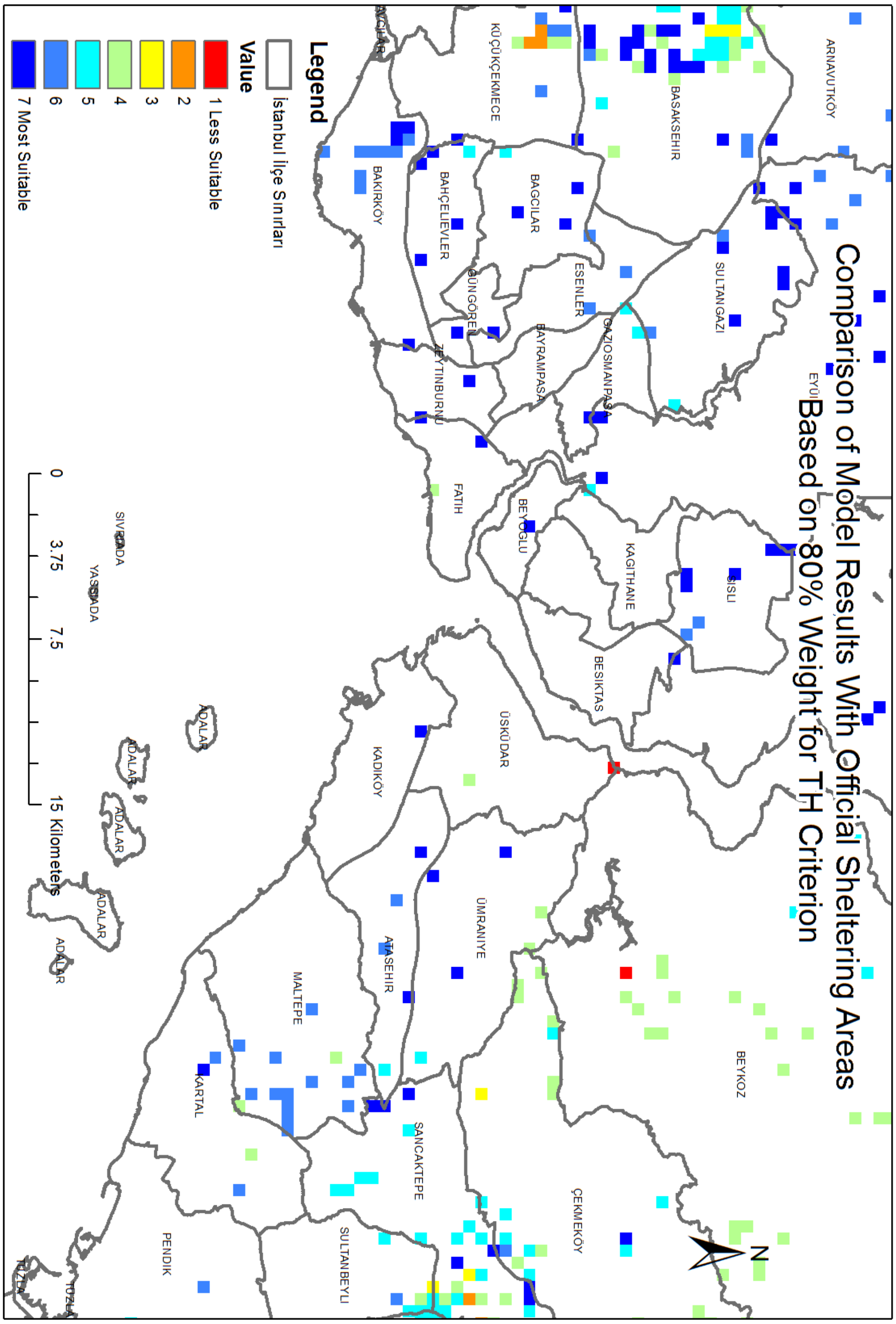

Figure A.54 : Comparison of model results with official sheltering areas based on 80% weight for TH criterion

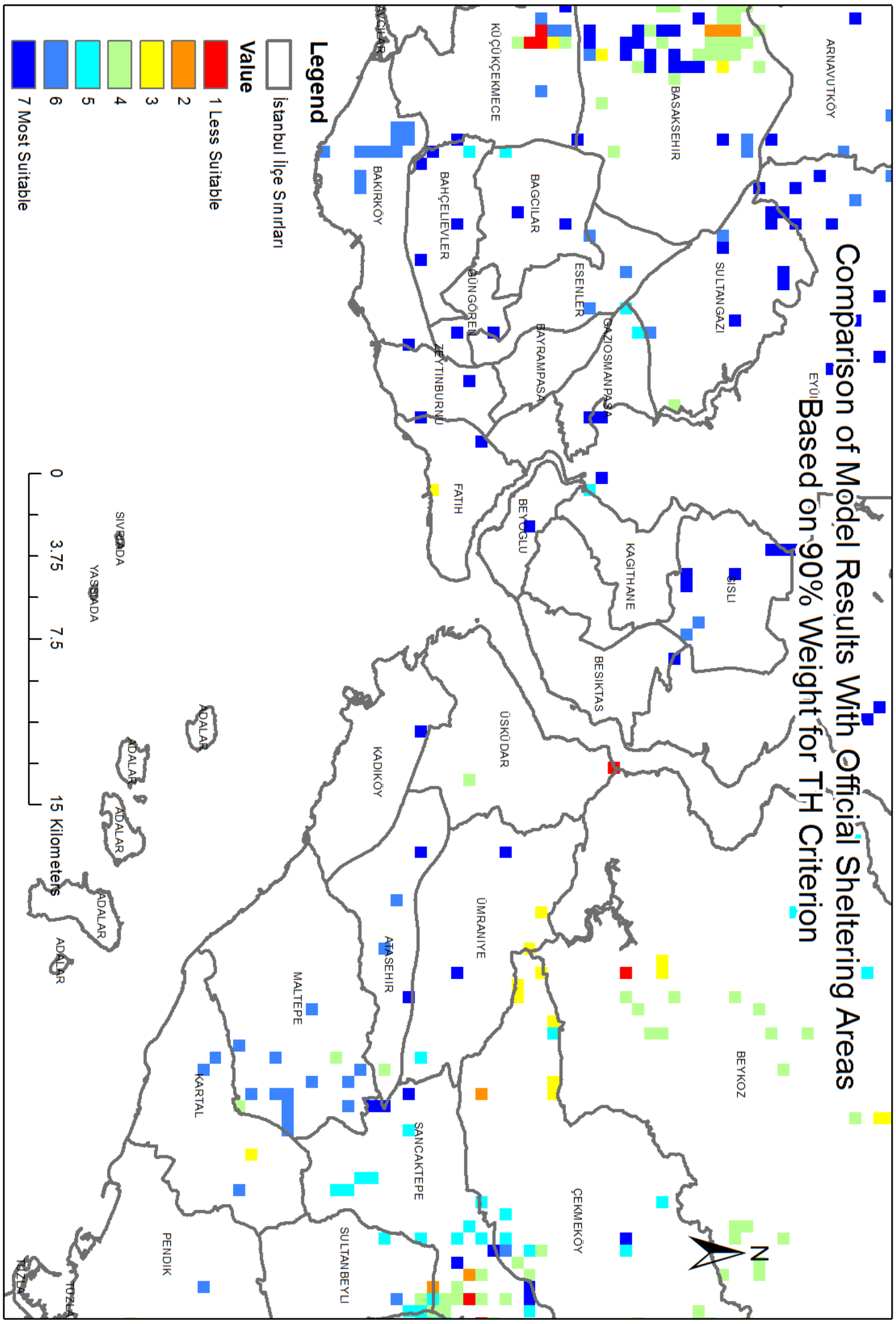

Figure A.55 : Comparison of model results with official sheltering areas based on 90% weight for TH criterion

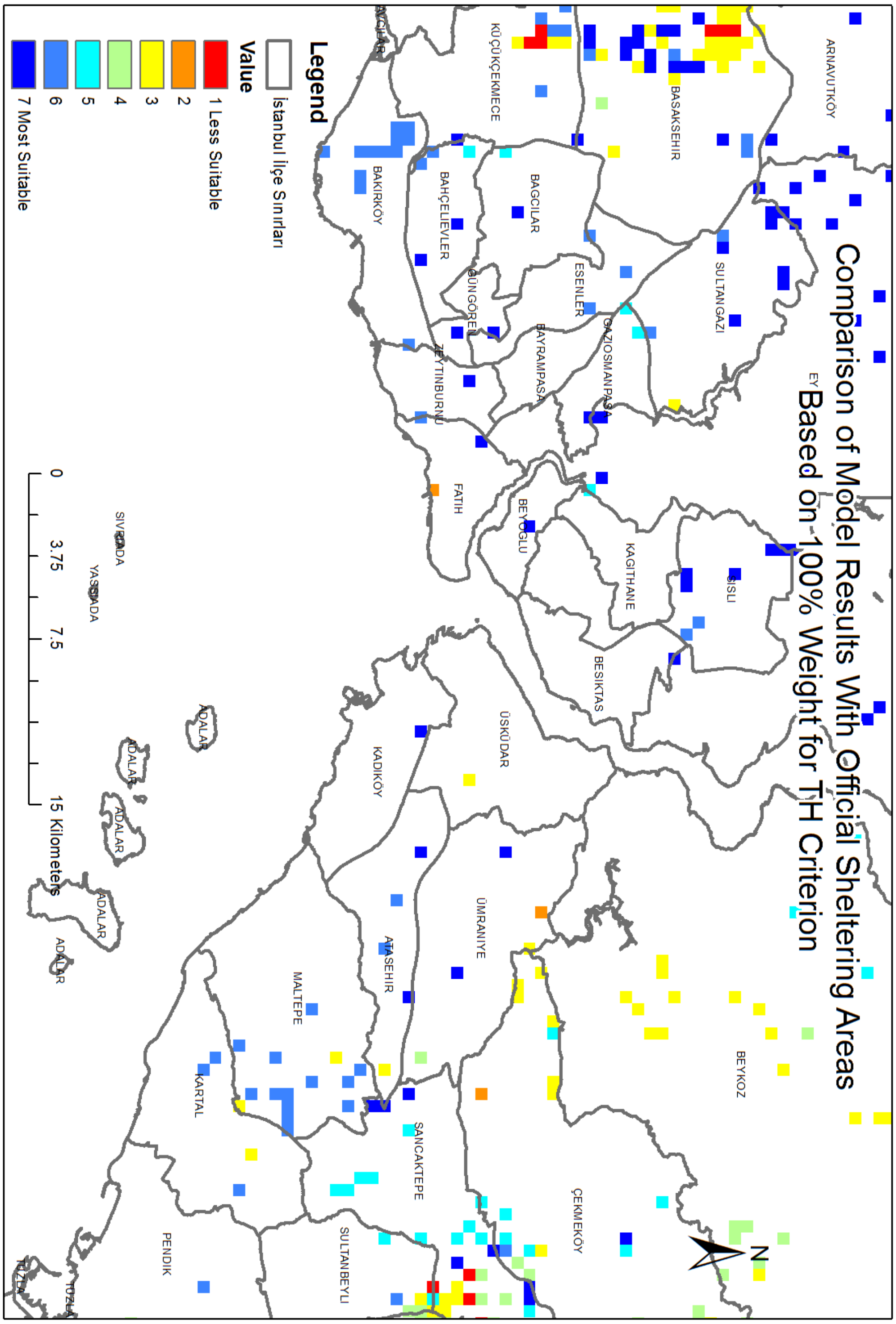

Figure A.56 : Comparison of model results with official sheltering areas based on 100% weight for TH criterion

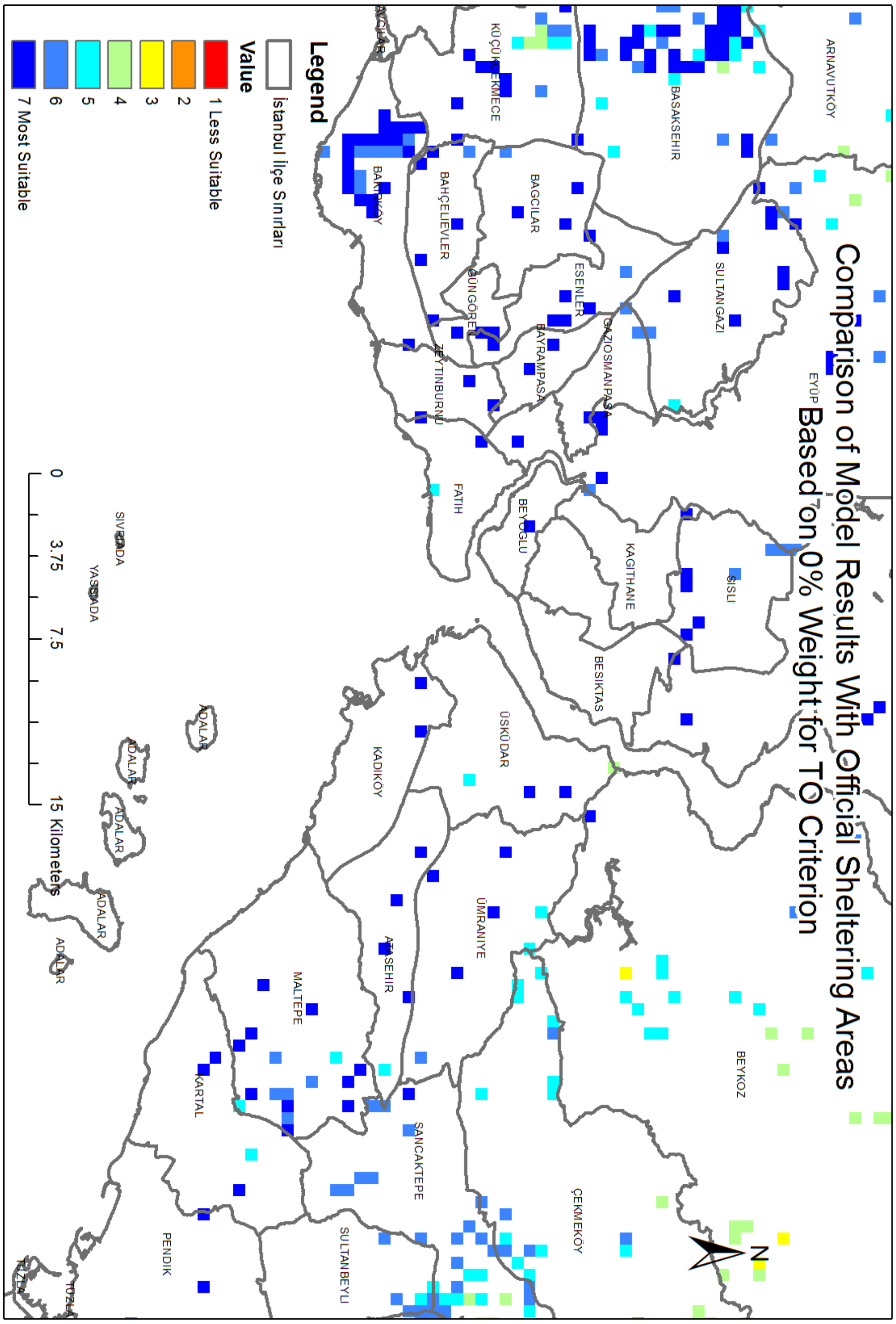

Figure A.57 : Comparison of model results with official sheltering areas based on 0% weight for TO criterion

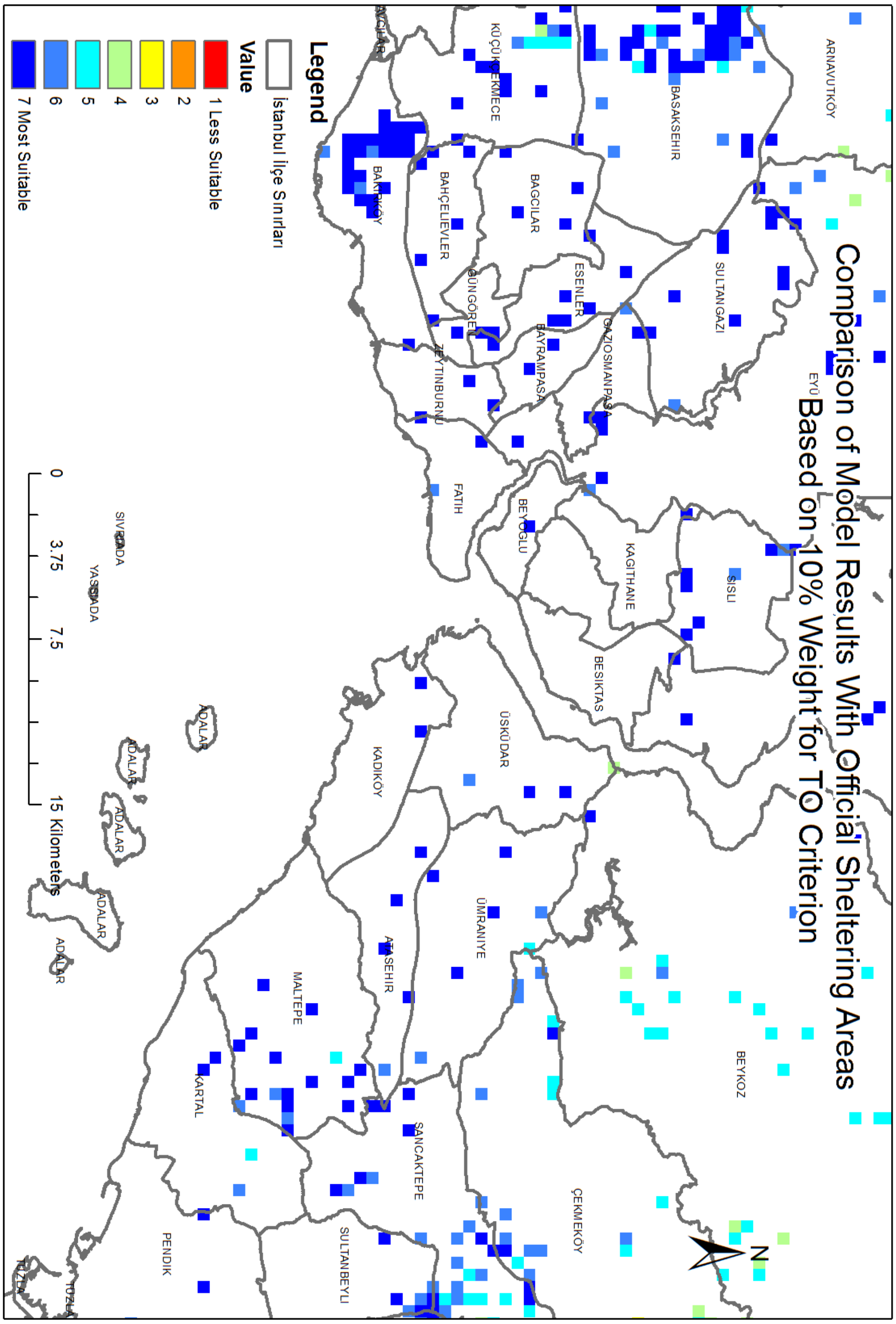

Figure A.58 : Comparison of model results with official sheltering areas based on 10% weight for TO criterion

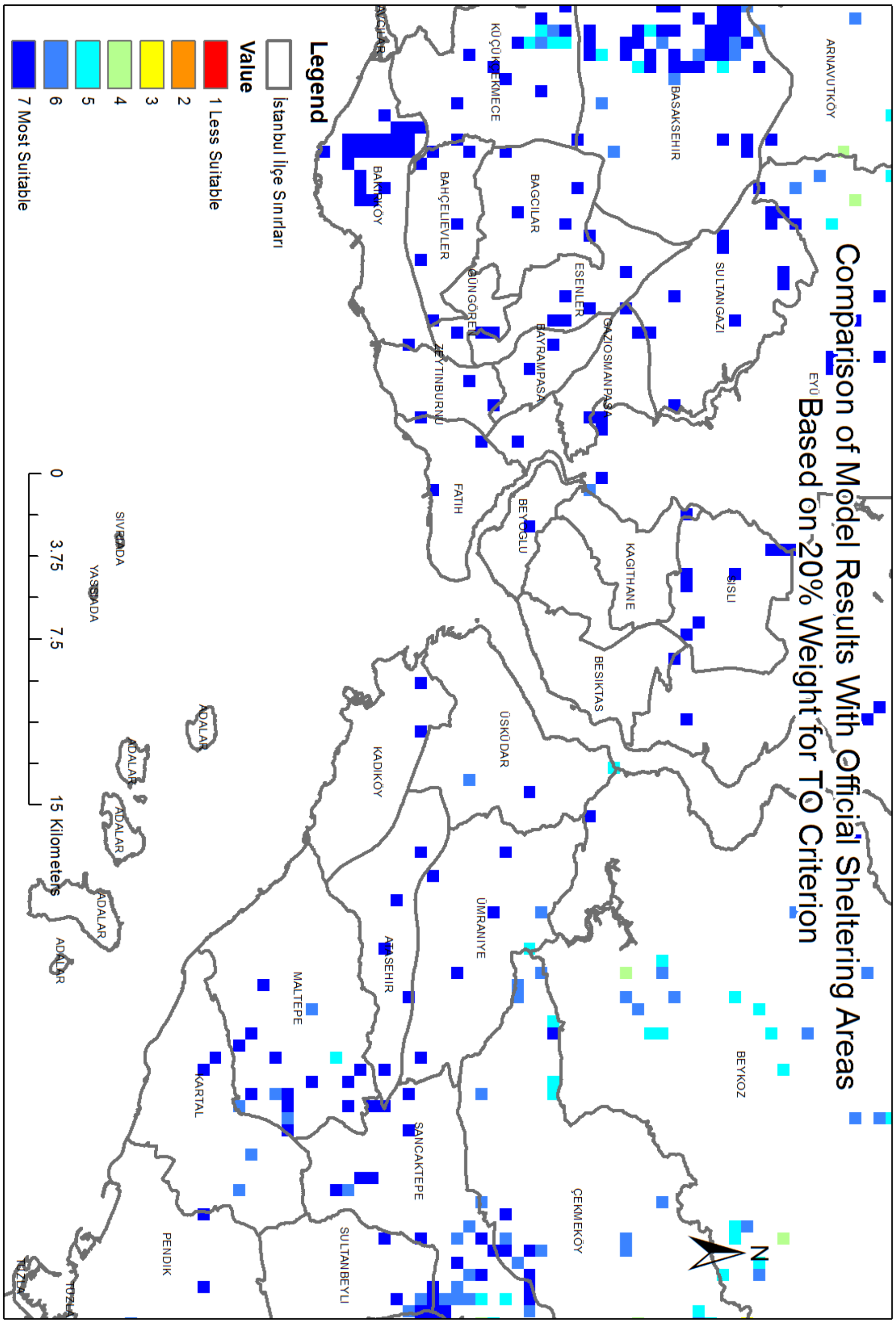

Figure A.59 : Comparison of model results with official sheltering areas based on 20% weight for TO criterion

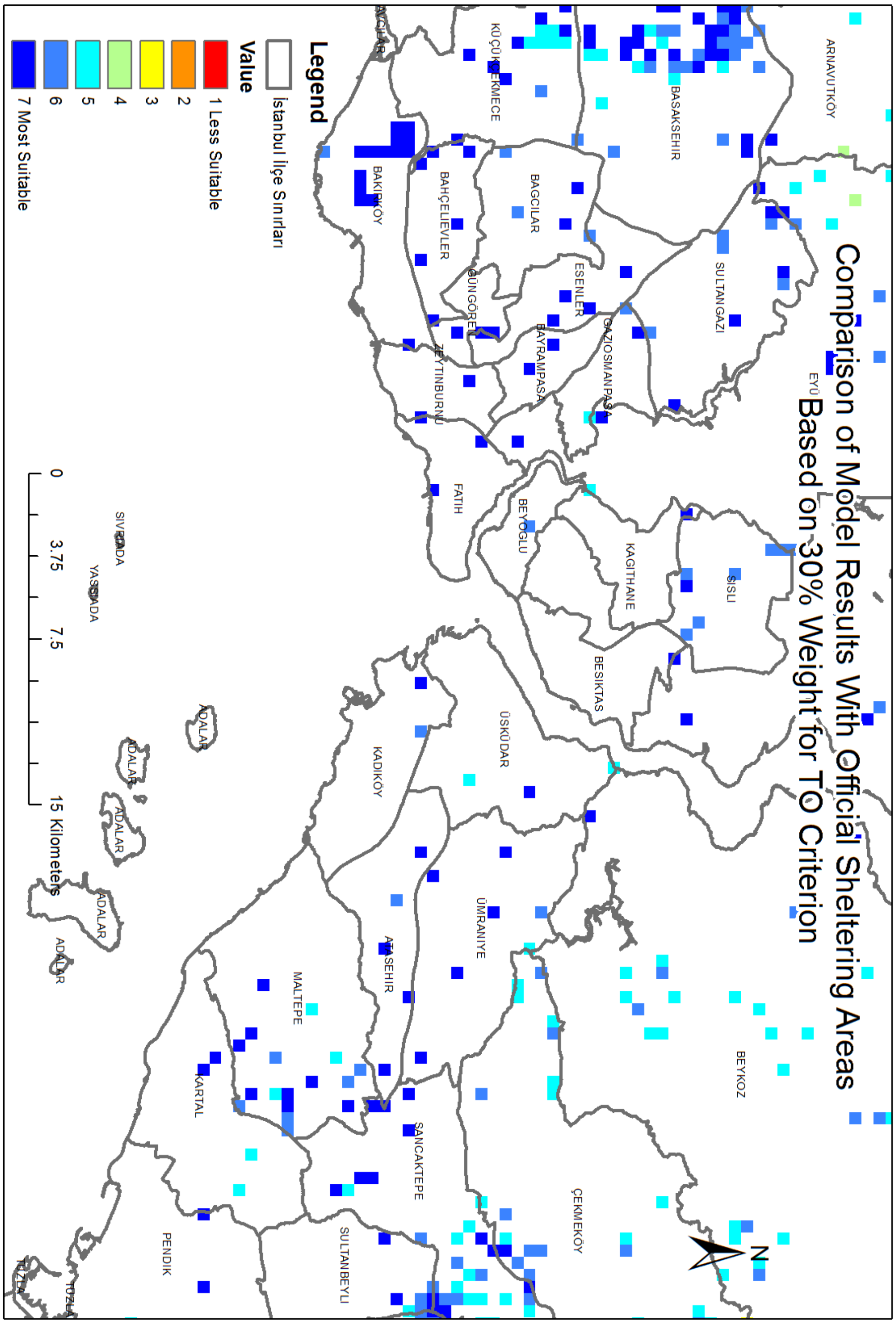

Figure A.60 : Comparison of model results with official sheltering areas based on 30% weight for TO criterion

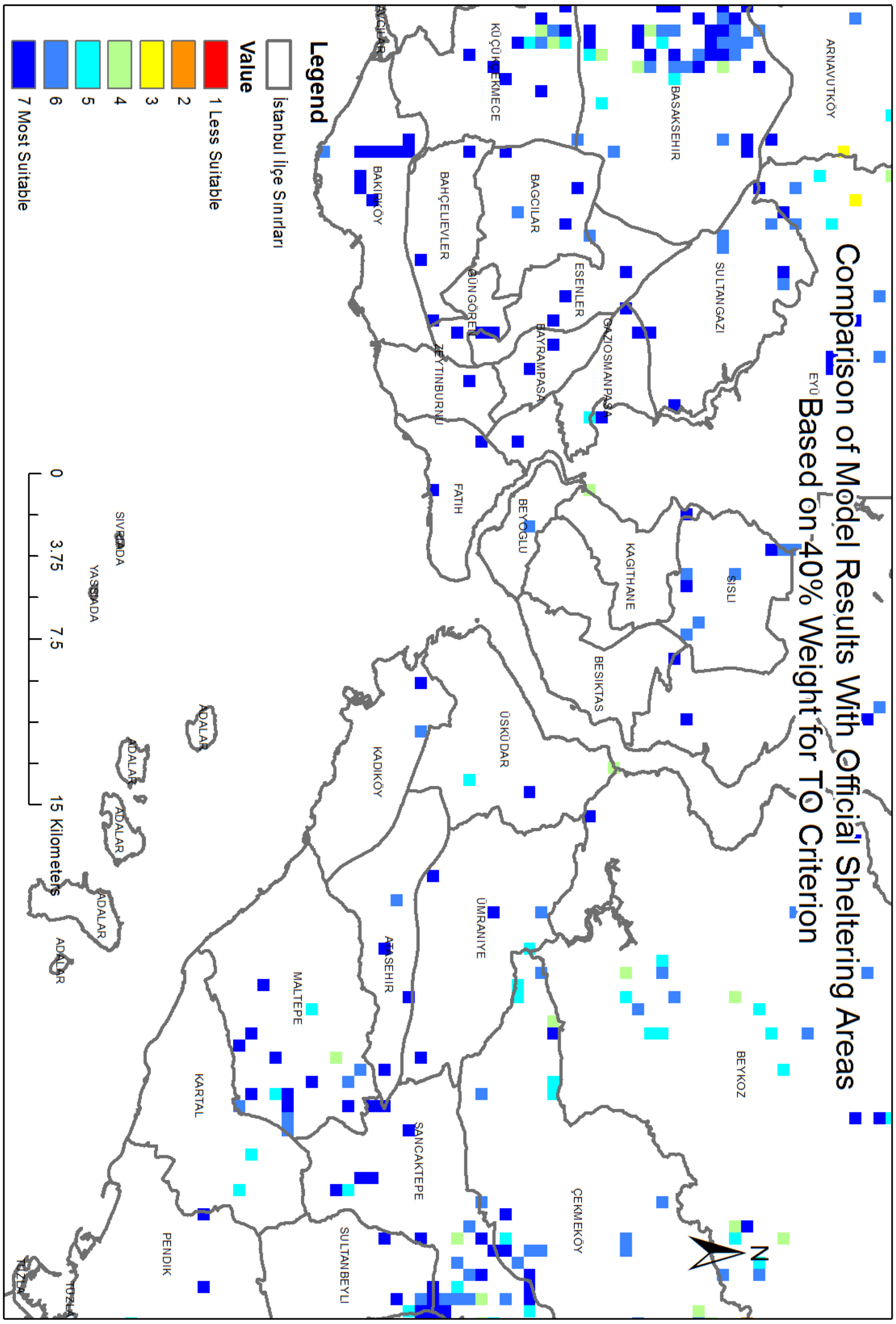

Figure A.61 : Comparison of model results with official sheltering areas based on 40% weight for TO criterion

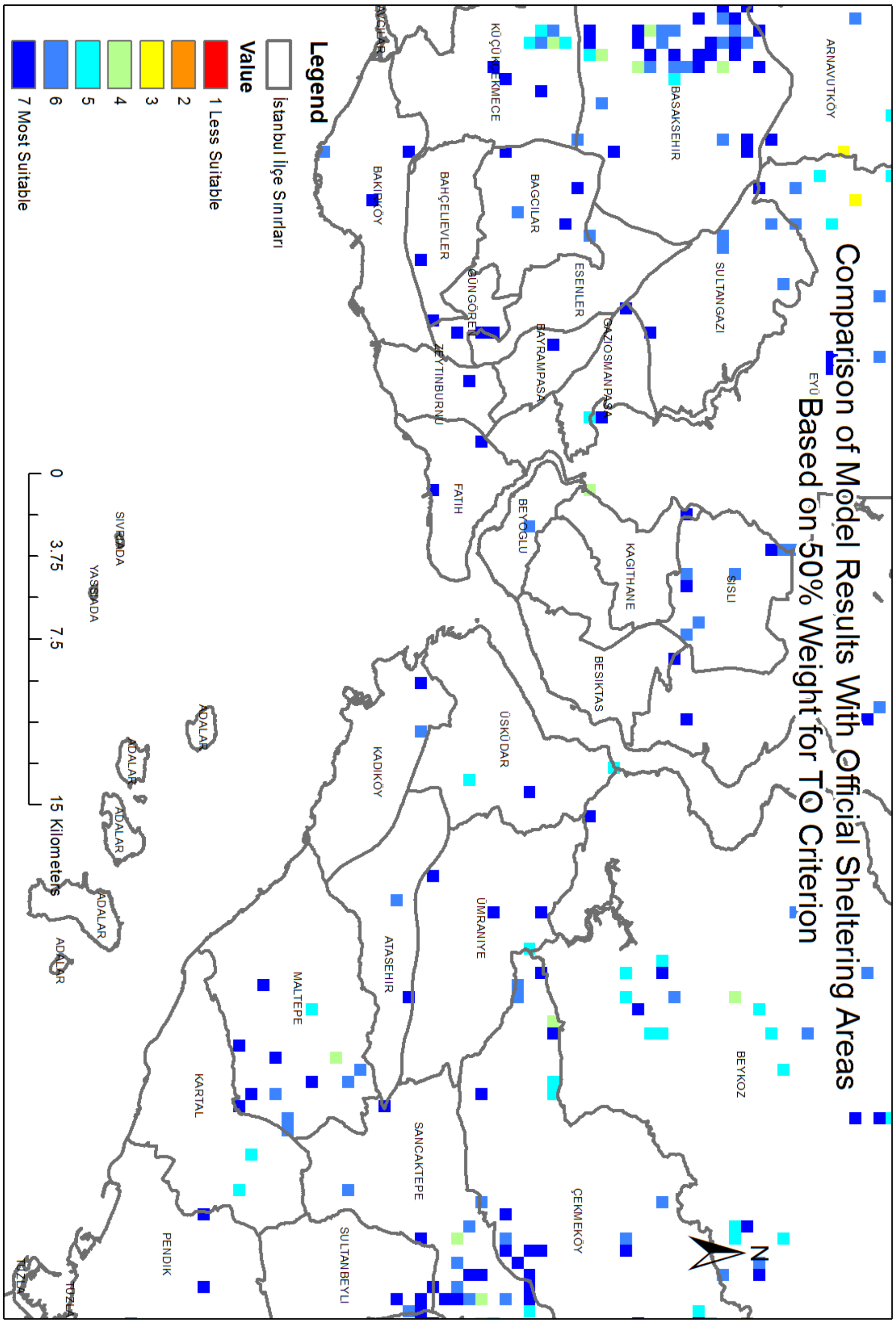

Figure A.62 : Comparison of model results with official sheltering areas based on 50% weight for TO criterion

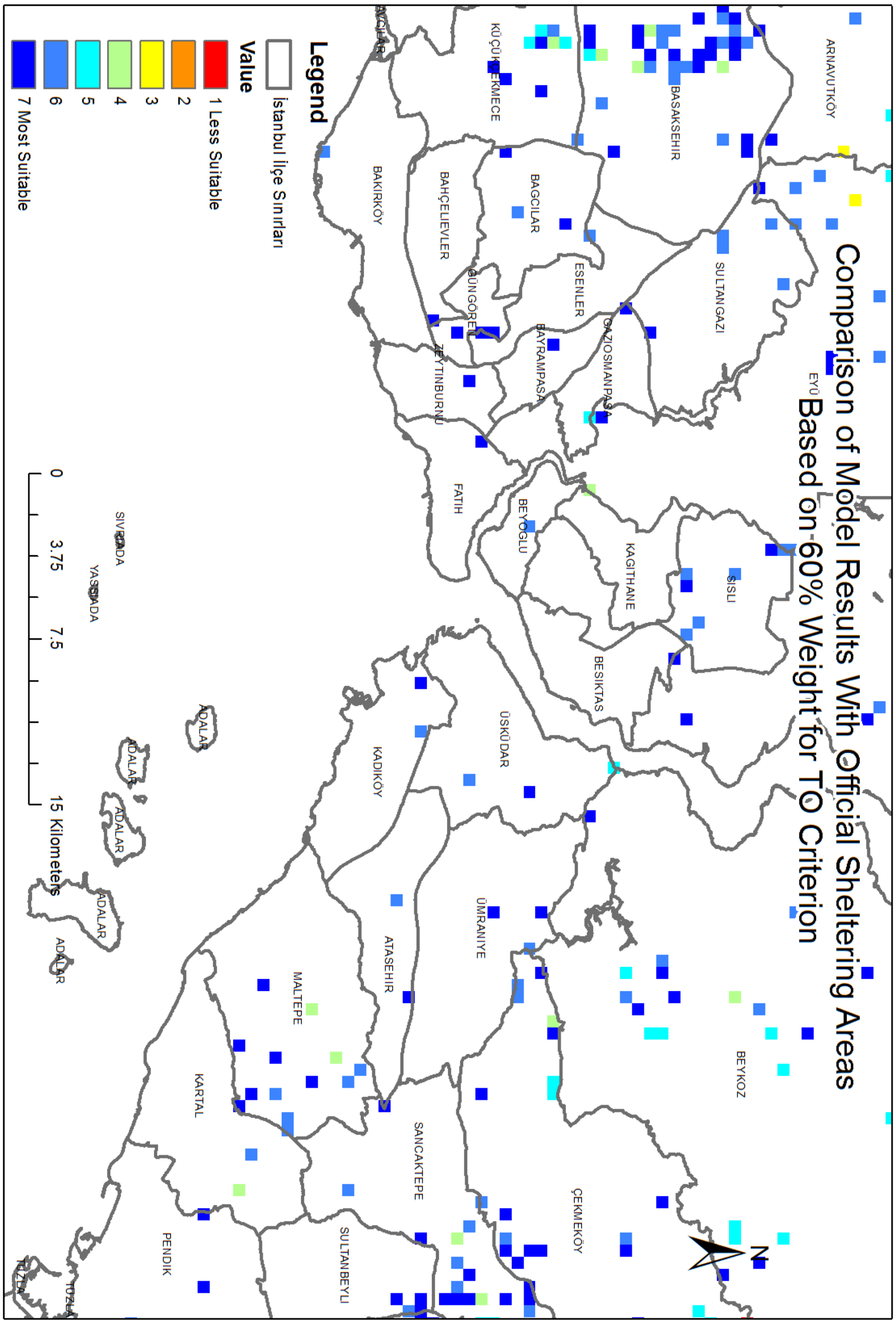

Figure A.63 : Comparison of model results with official sheltering areas based on 60% weight for TO criterion

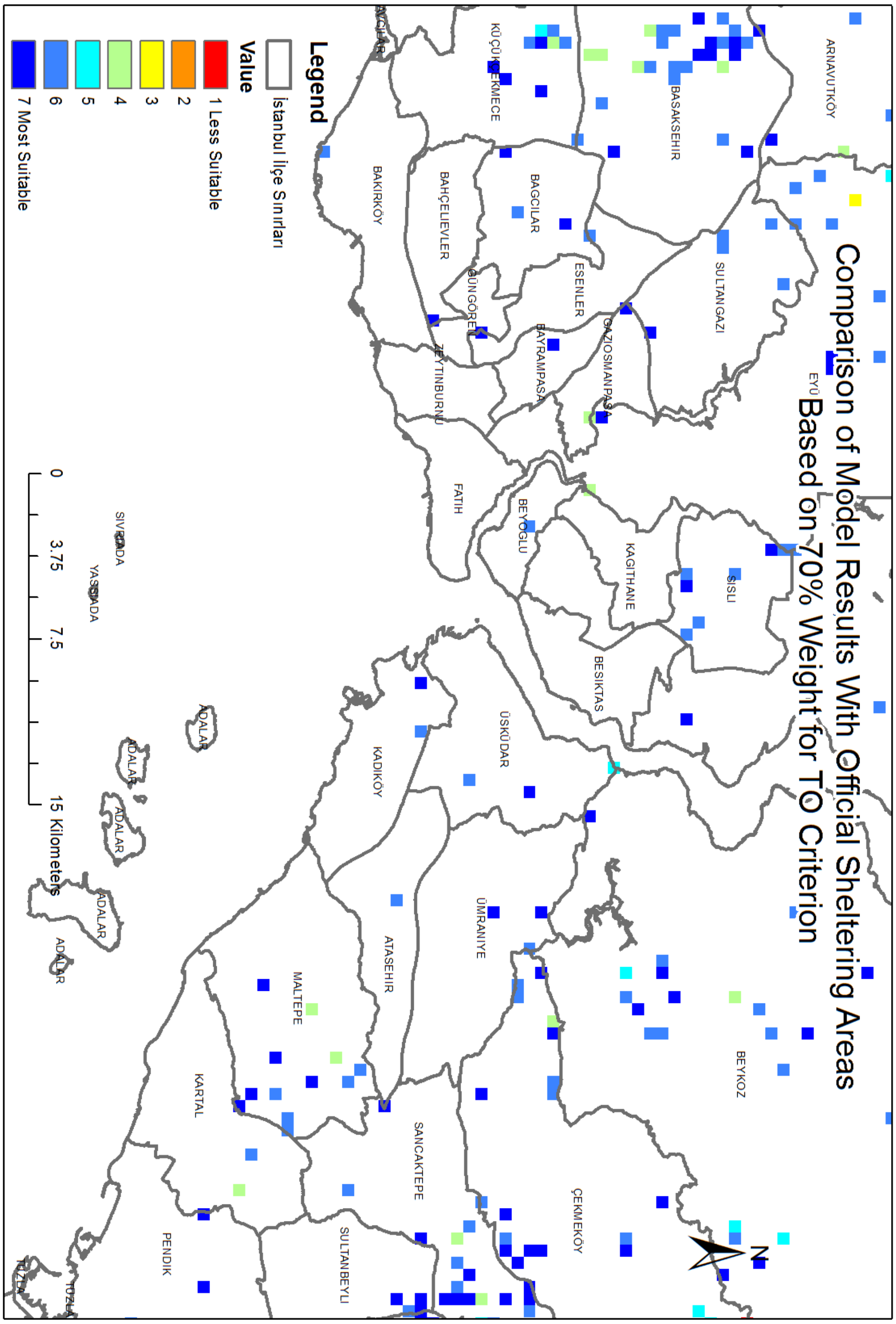

Figure A.64 : Comparison of model results with official sheltering areas based on 70% weight for TO criterion

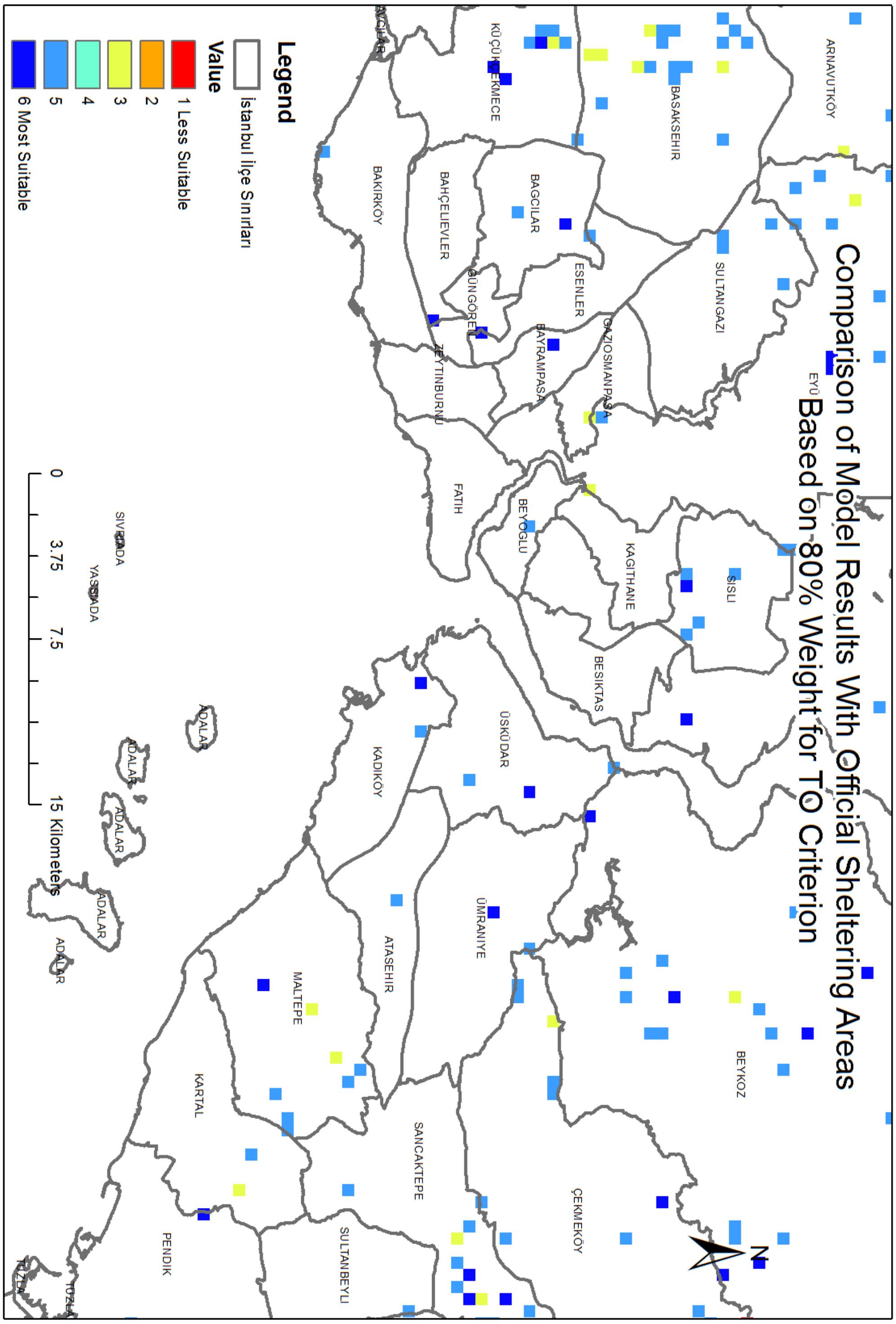

Figure A.65 : Comparison of model results with official sheltering areas based on 80% weight for TO criterion

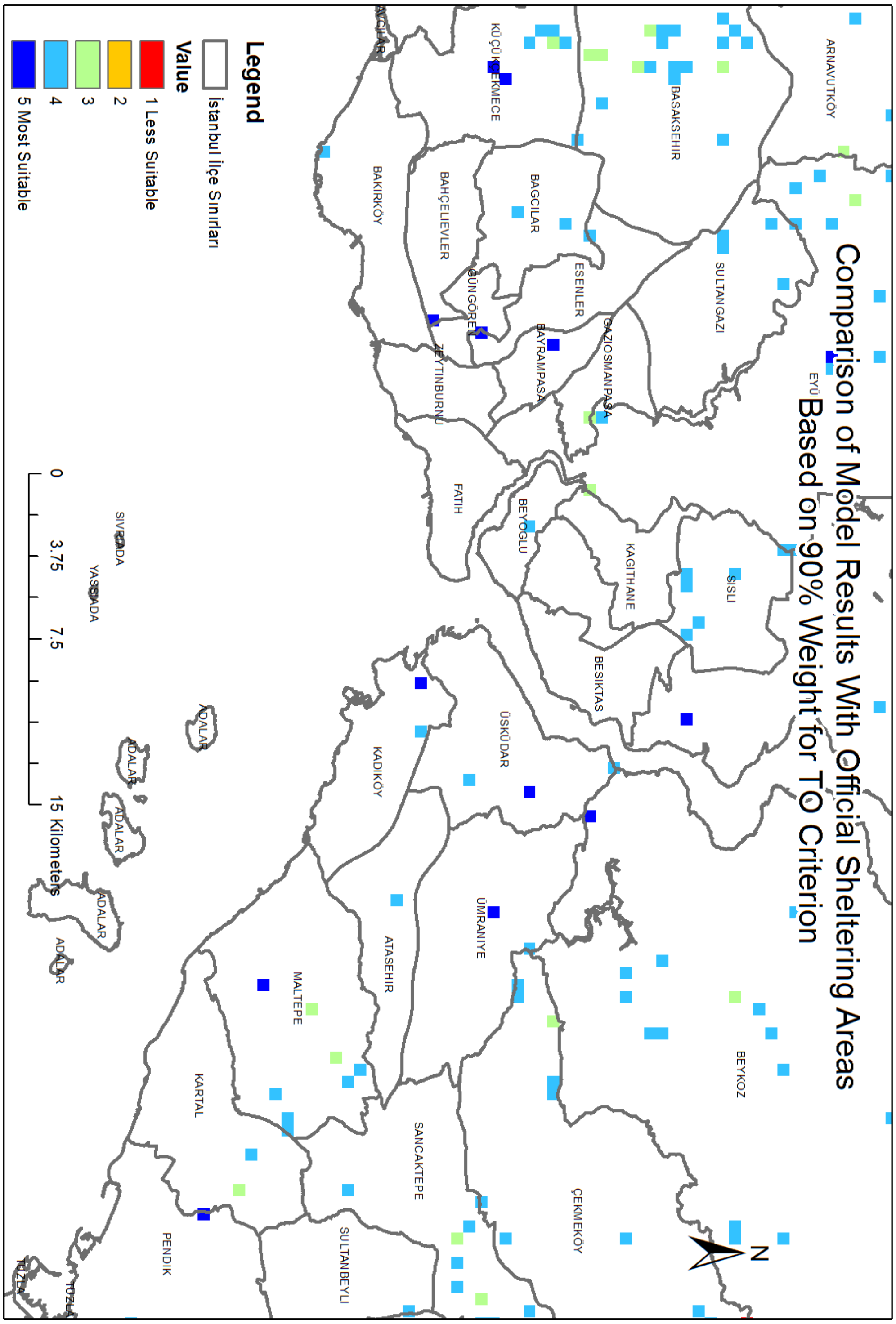

Figure A.66 : Comparison of model results with official sheltering areas based on 90% weight for TO criterion

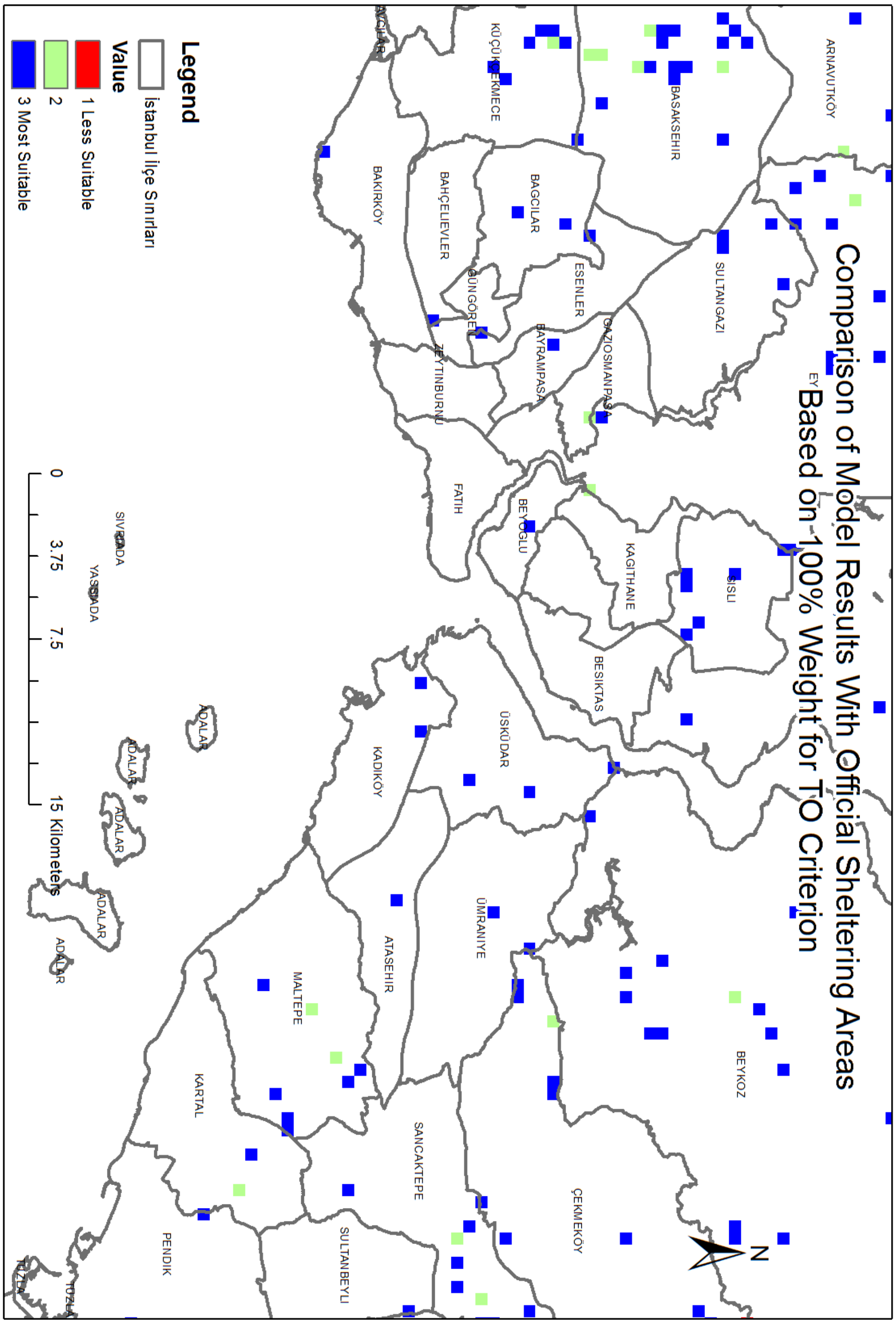

Figure A.67 : Comparison of model results with official sheltering areas based on 100% weight for TO criterion

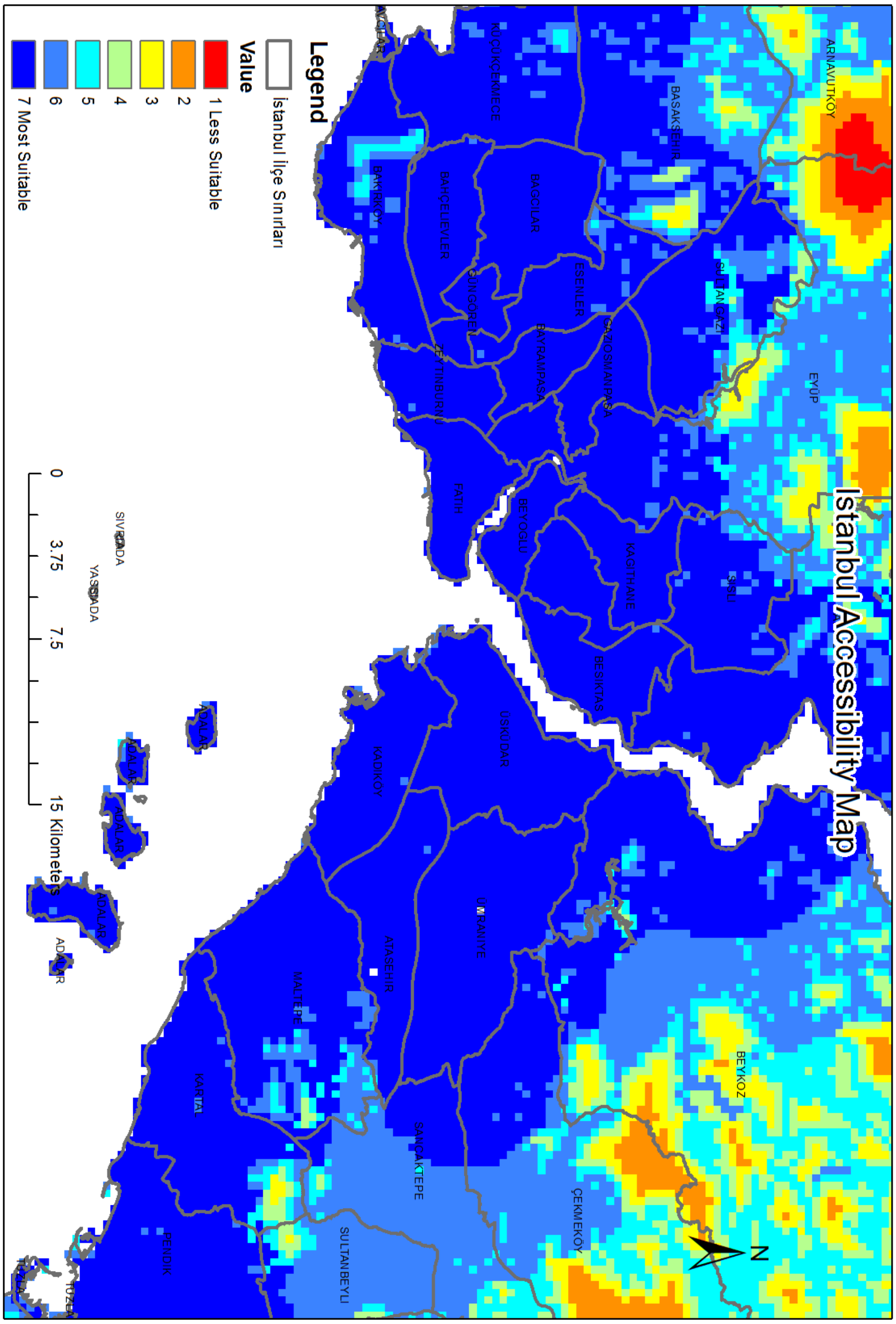

Figure A.68 : Istanbul Accessibility Map

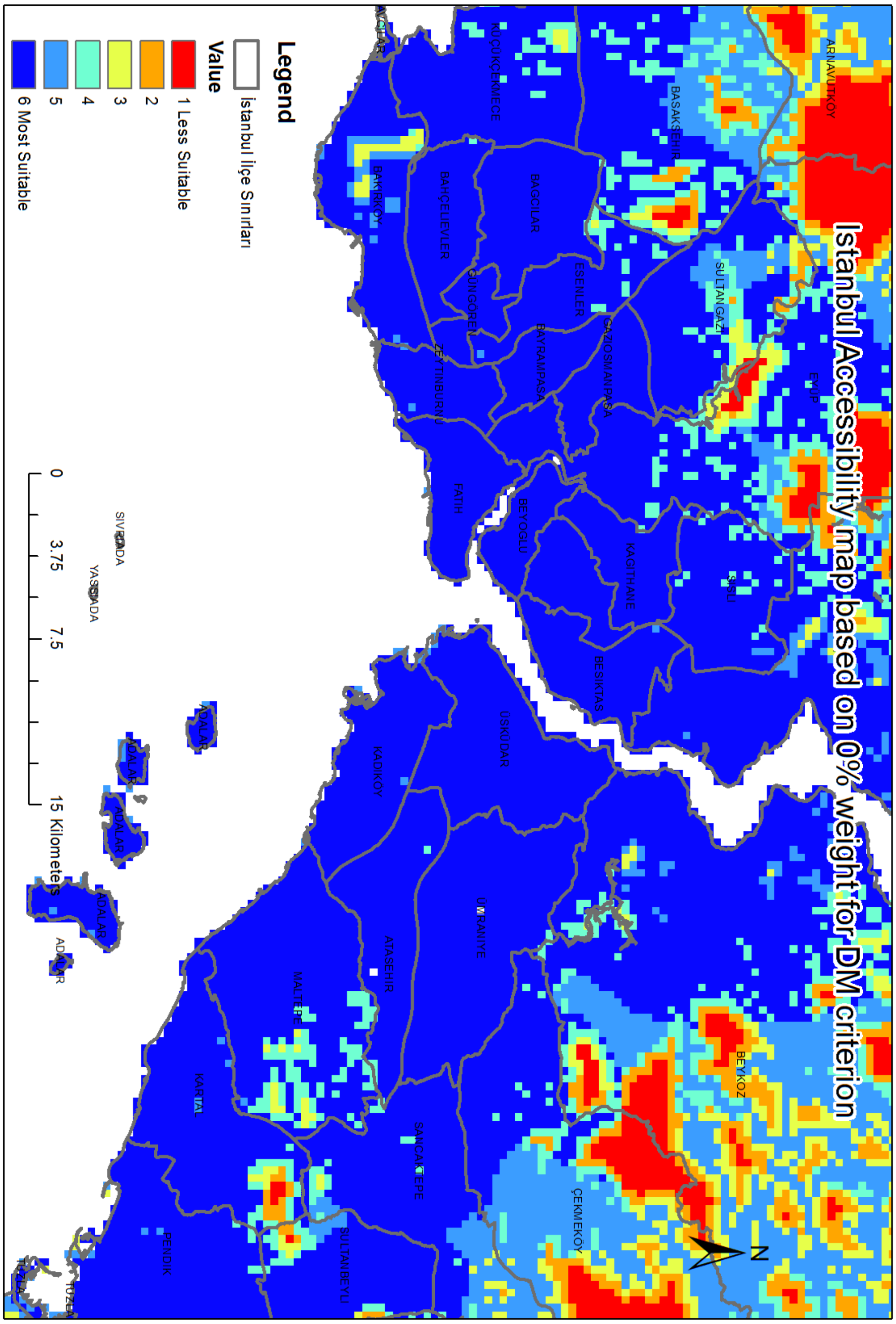

Figure A.69 : Istanbul Accessibility map based on 0% weight for DM criterion

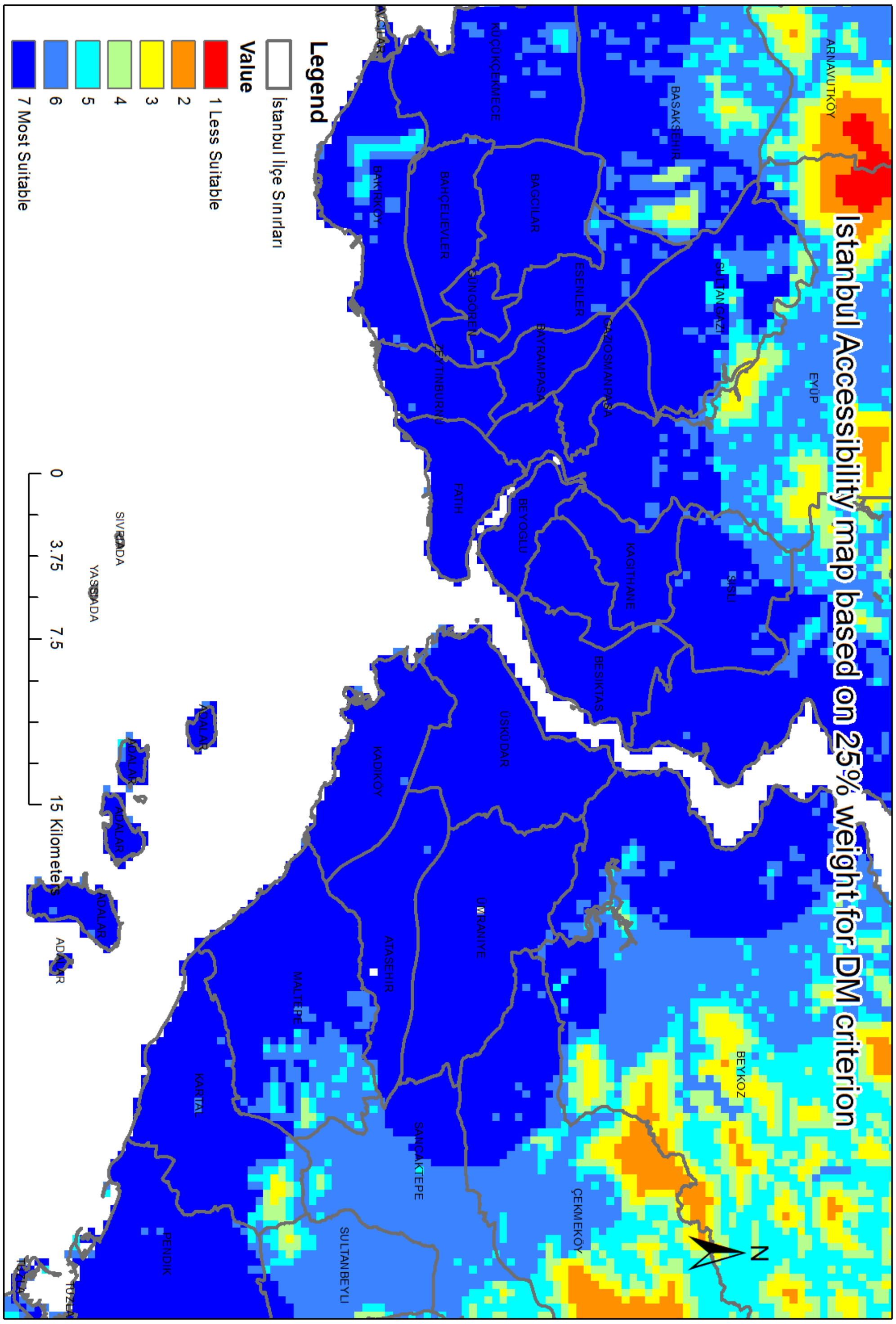

Figure A.70 : Istanbul Accessibility map based on 25% weight for DM criterion

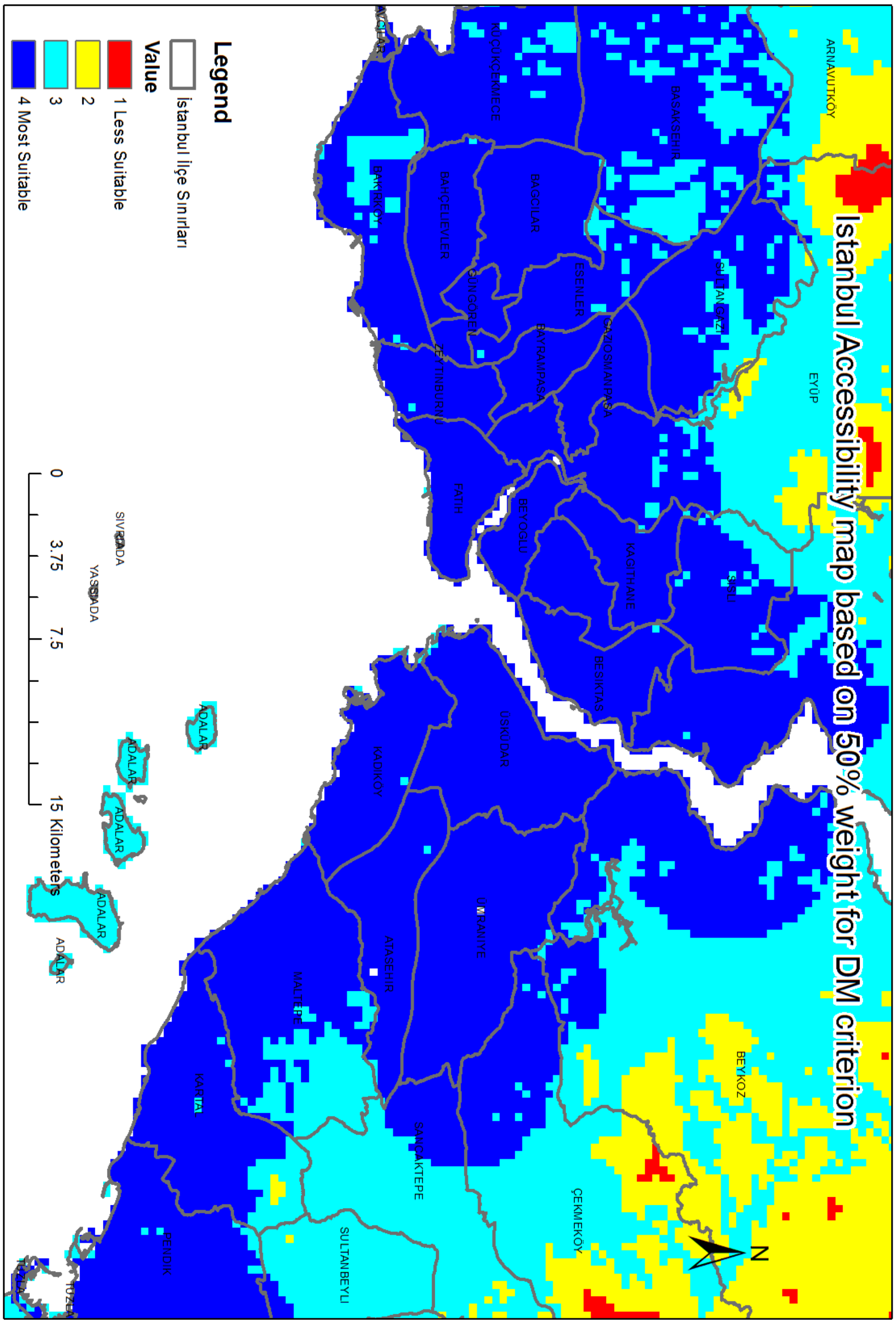

Figure A.71 : Istanbul Accessibility map based on 50% weight for DM criterion

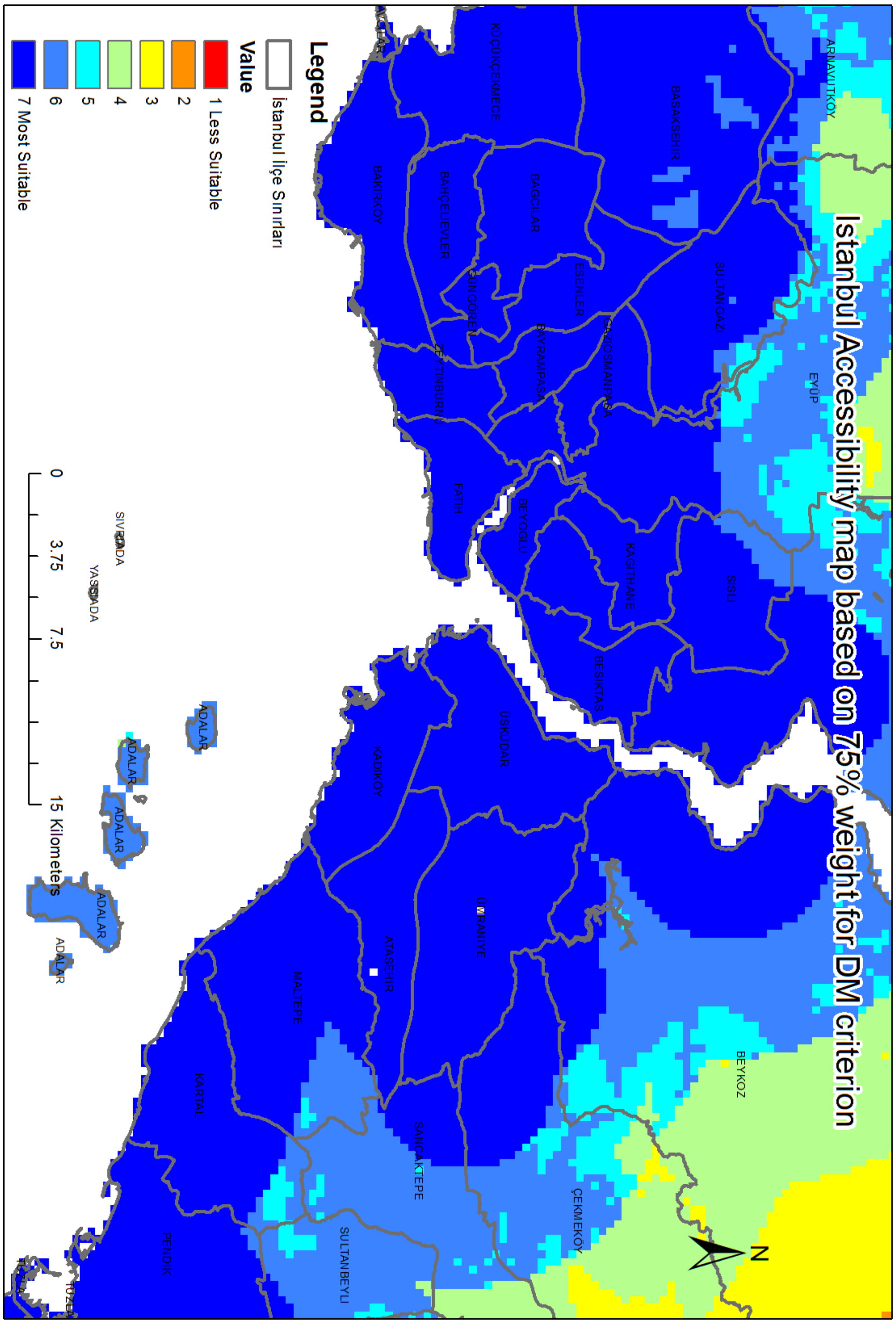

Figure A.72 : Istanbul Accessibility map based on 75% weight for DM criterion

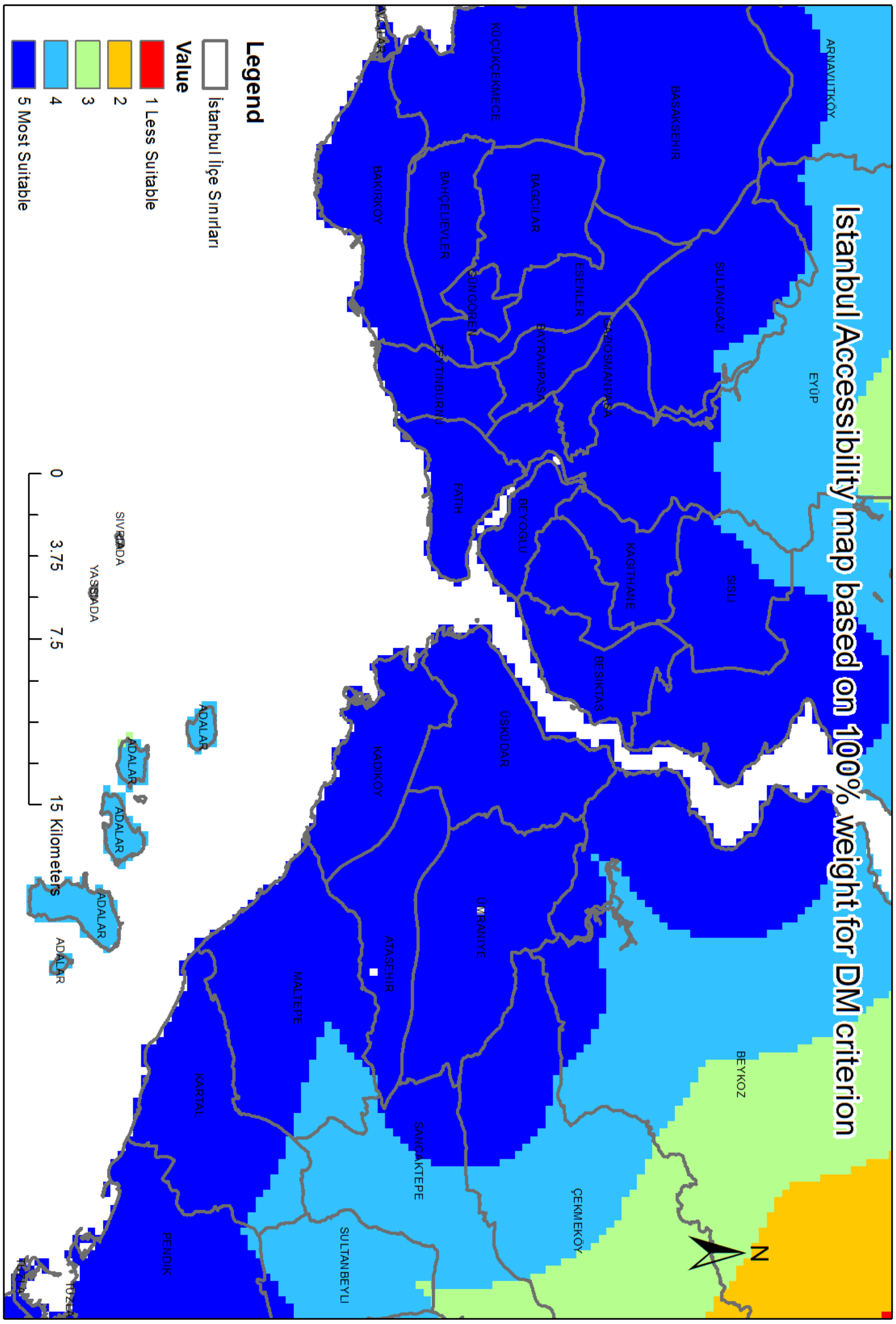

Figure A.73 : Istanbul Accessibility map based on 100% weight for DM criterion

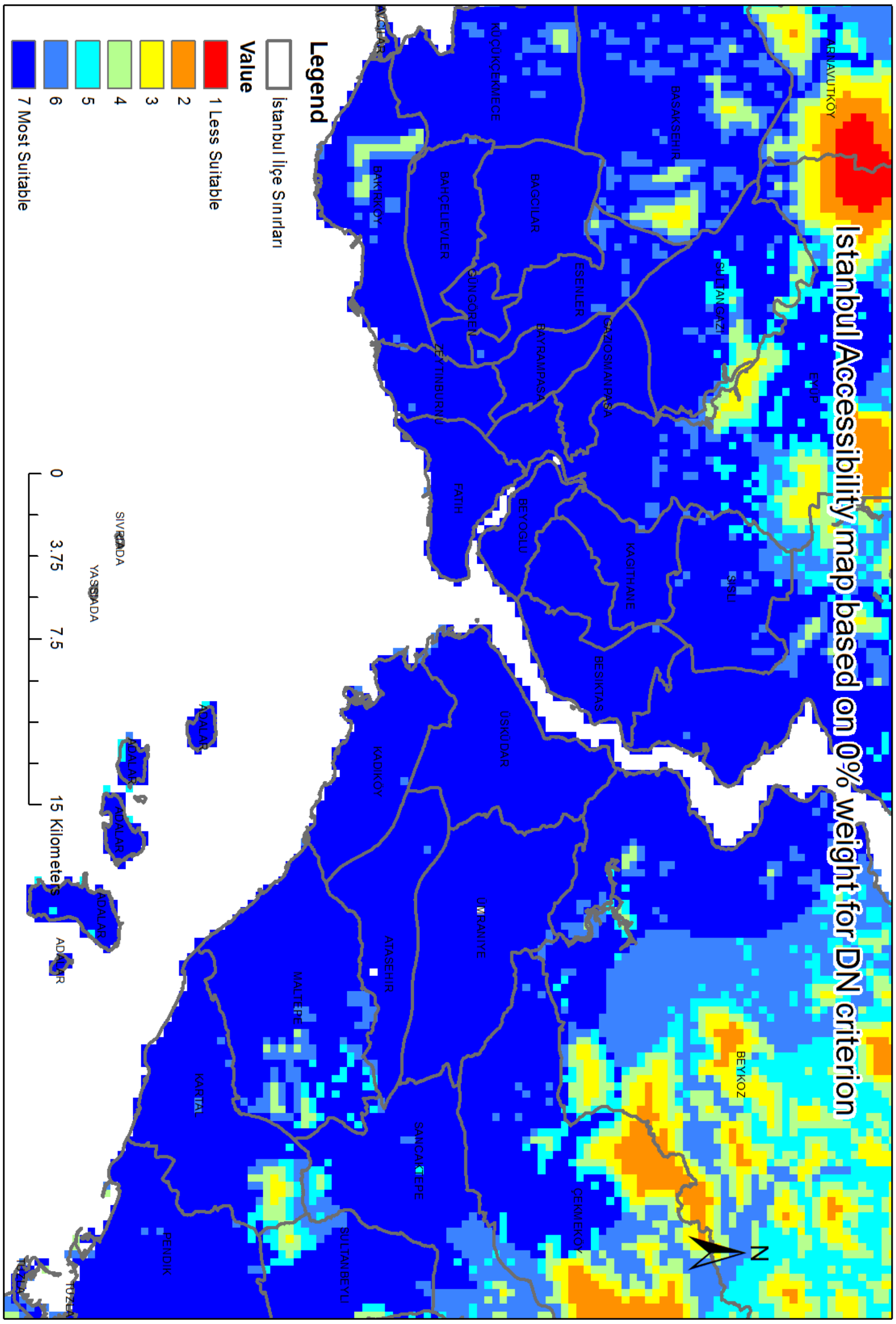

Figure A.74 : Istanbul Accessibility map based on 0% weight for DN criterion

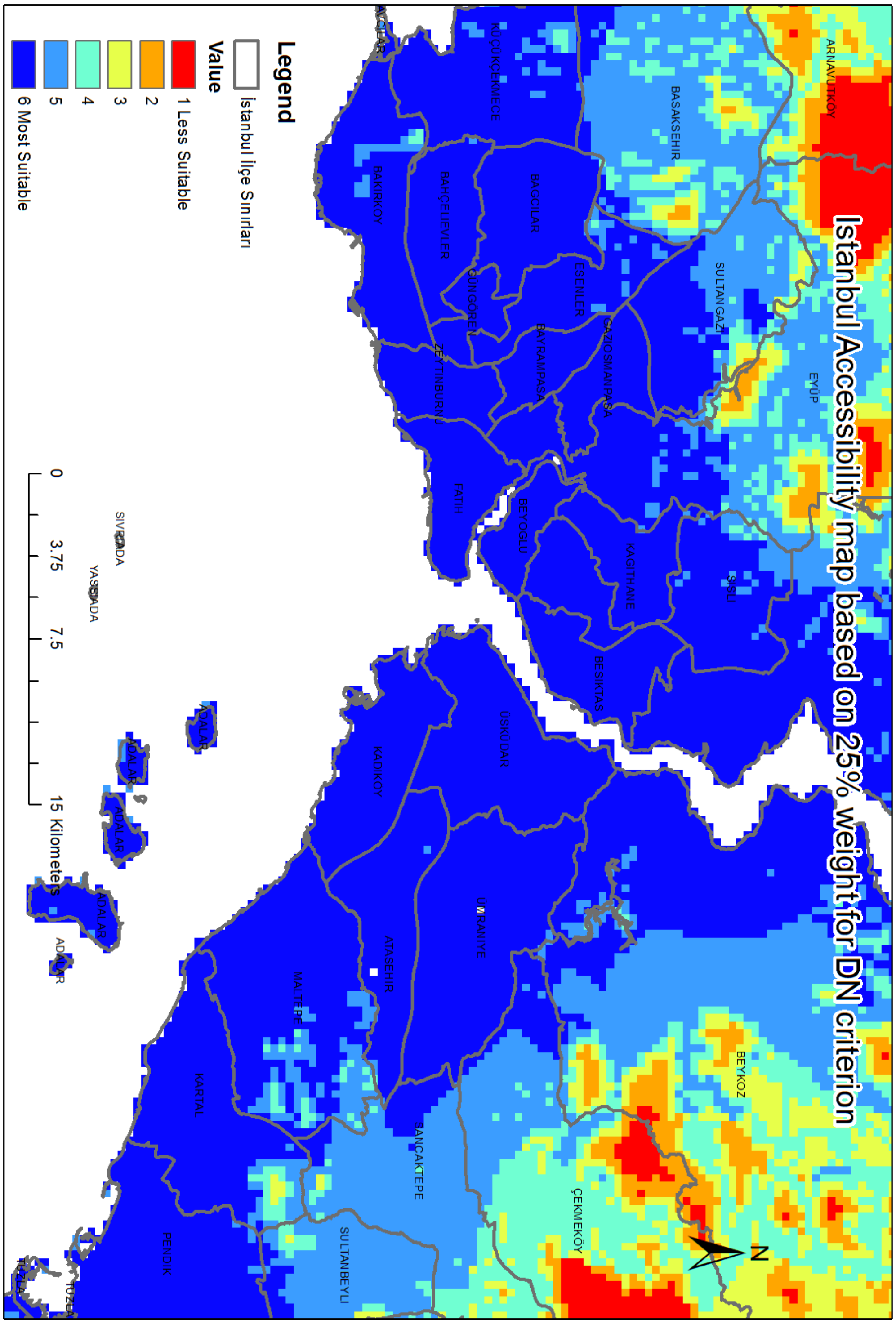

Figure A.75 : Istanbul Accessibility map based on 25% weight for DN criterion

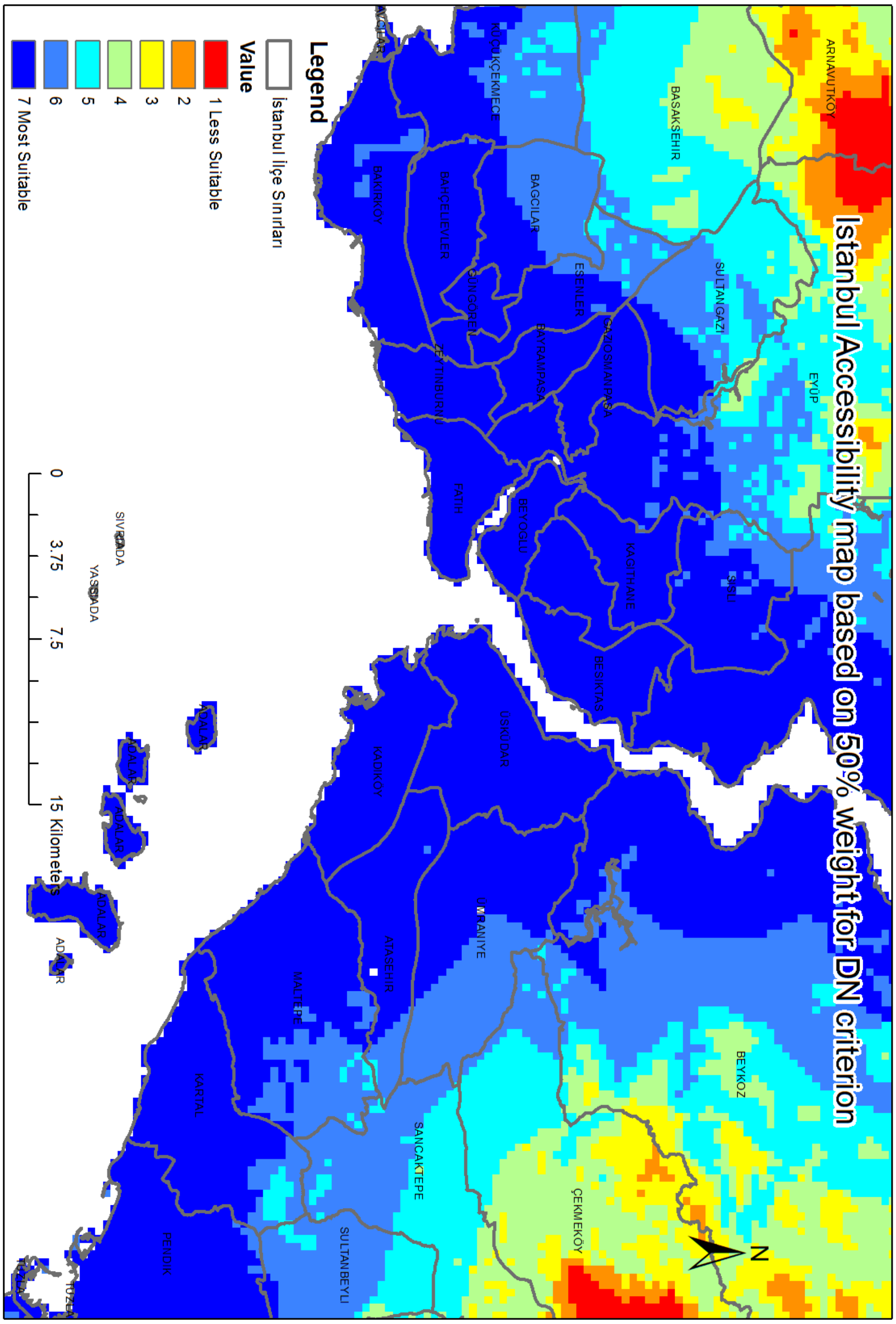

Figure A.76 : Istanbul Accessibility map based on 50% weight for DN criterion

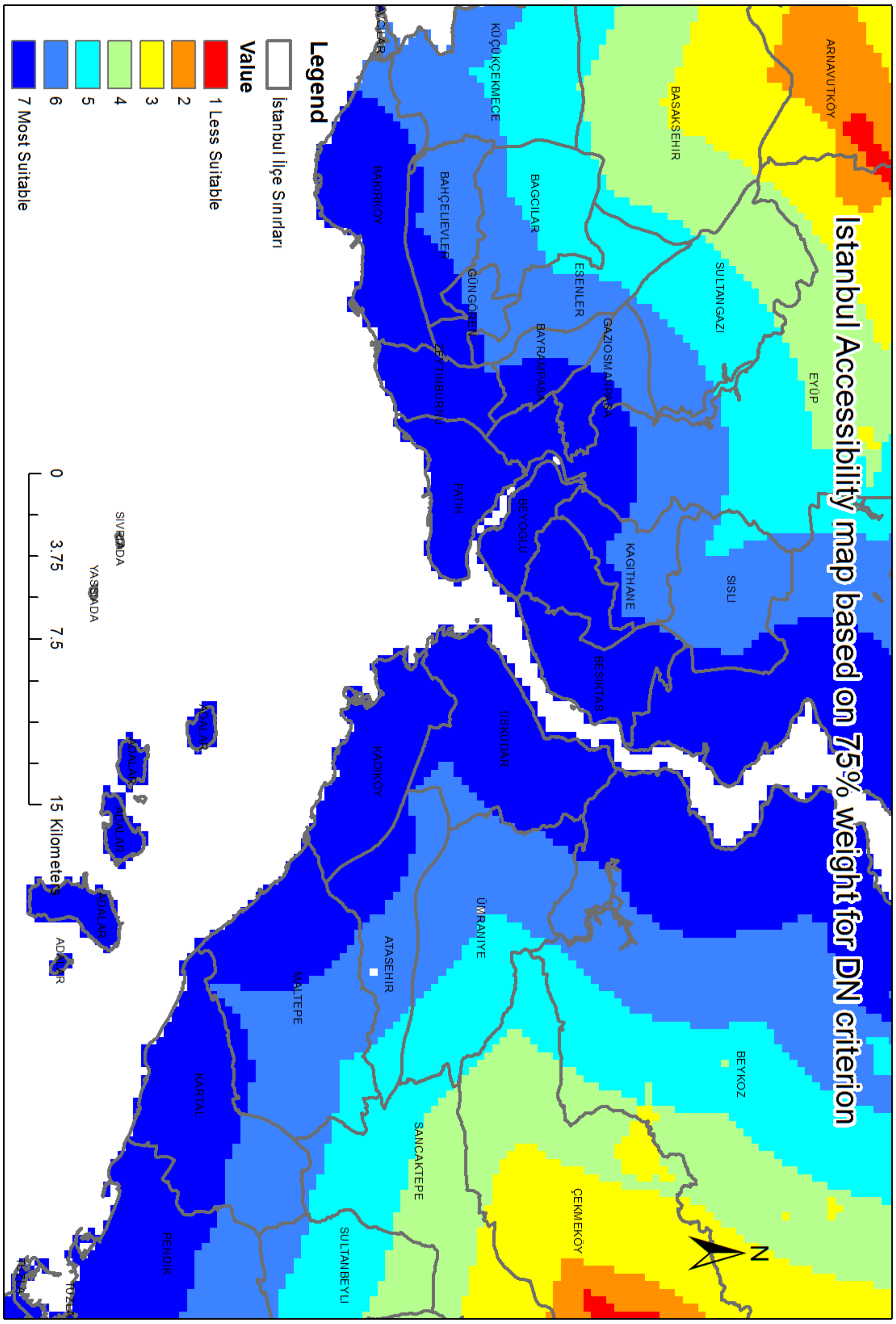

Figure A.77 : Istanbul Accessibility map based on 75% weight for DN criterion

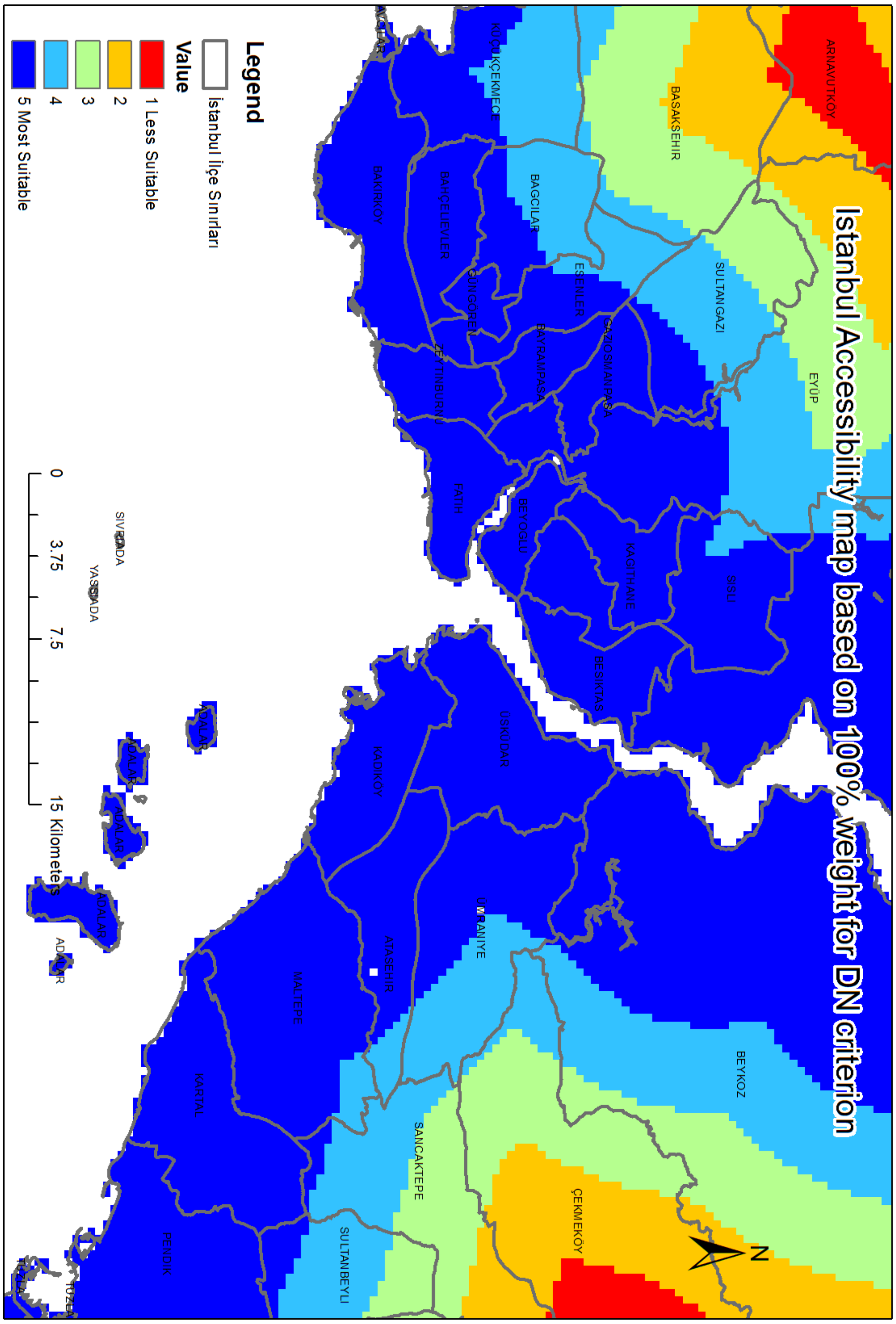

Figure A.78 : Istanbul Accessibility map based on 100% weight for DN criterion

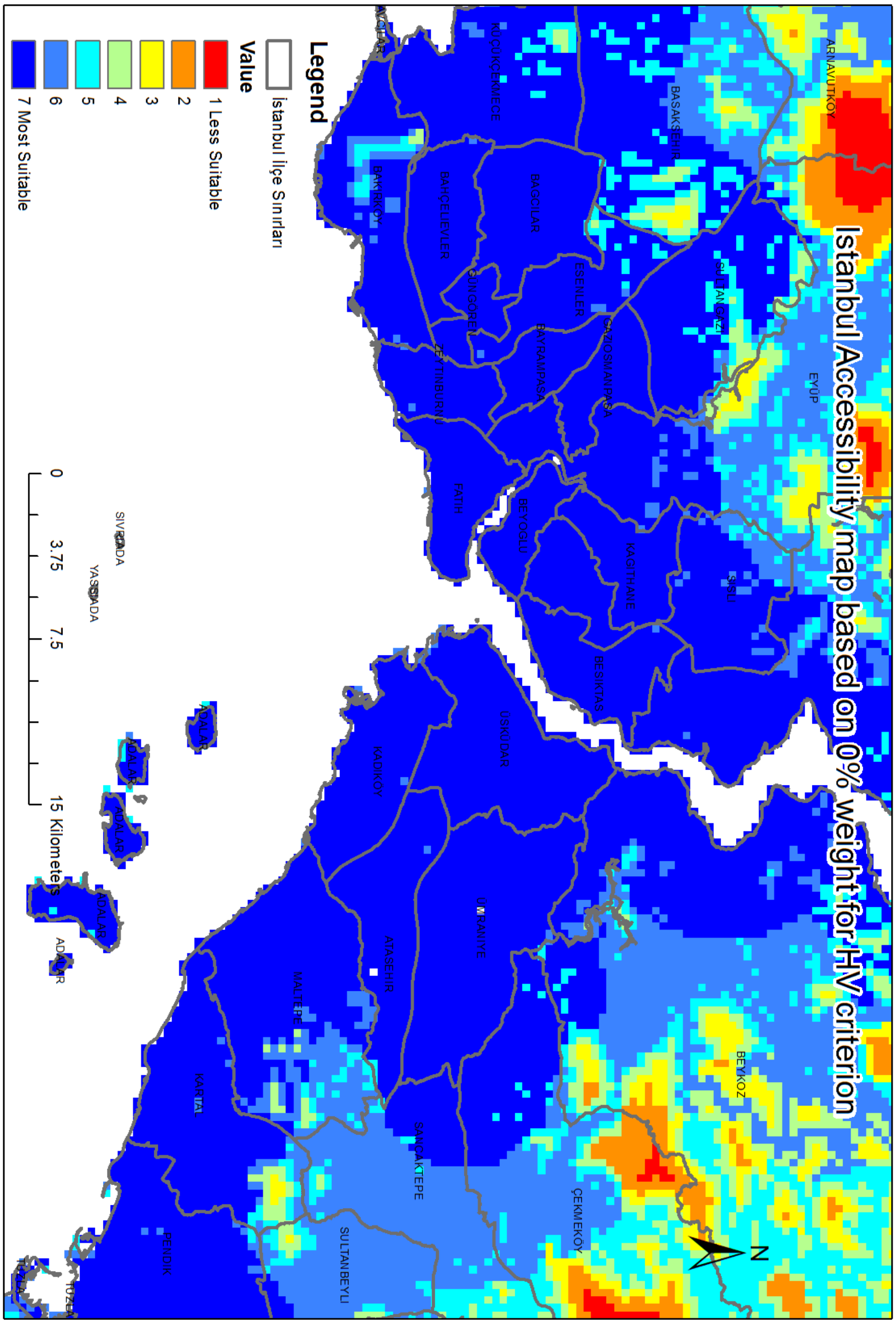

Figure A.79 : Istanbul Accessibility map based on 0% weight for HV criterion

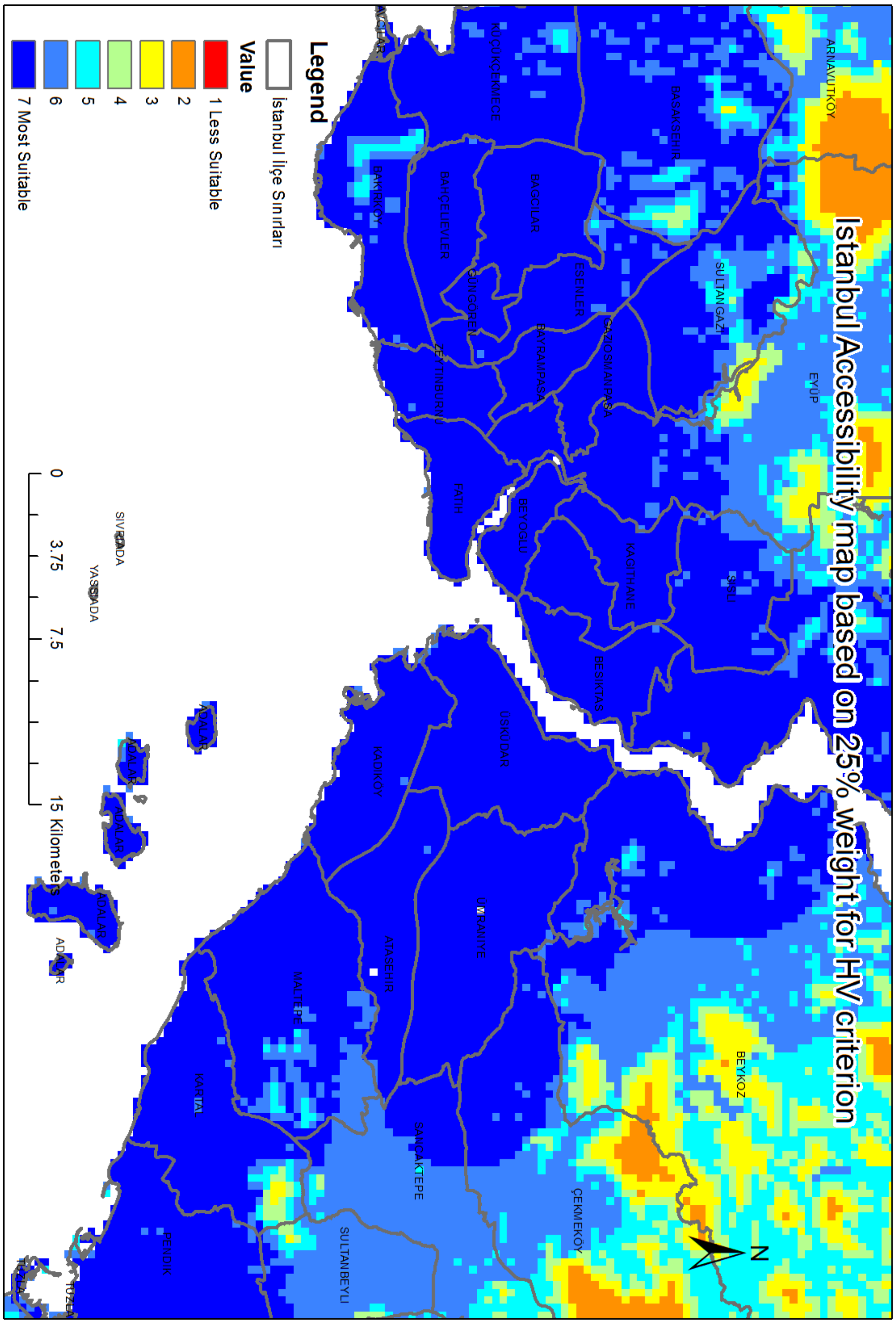

Figure A.80 : Istanbul Accessibility map based on 25% weight for HV criterion

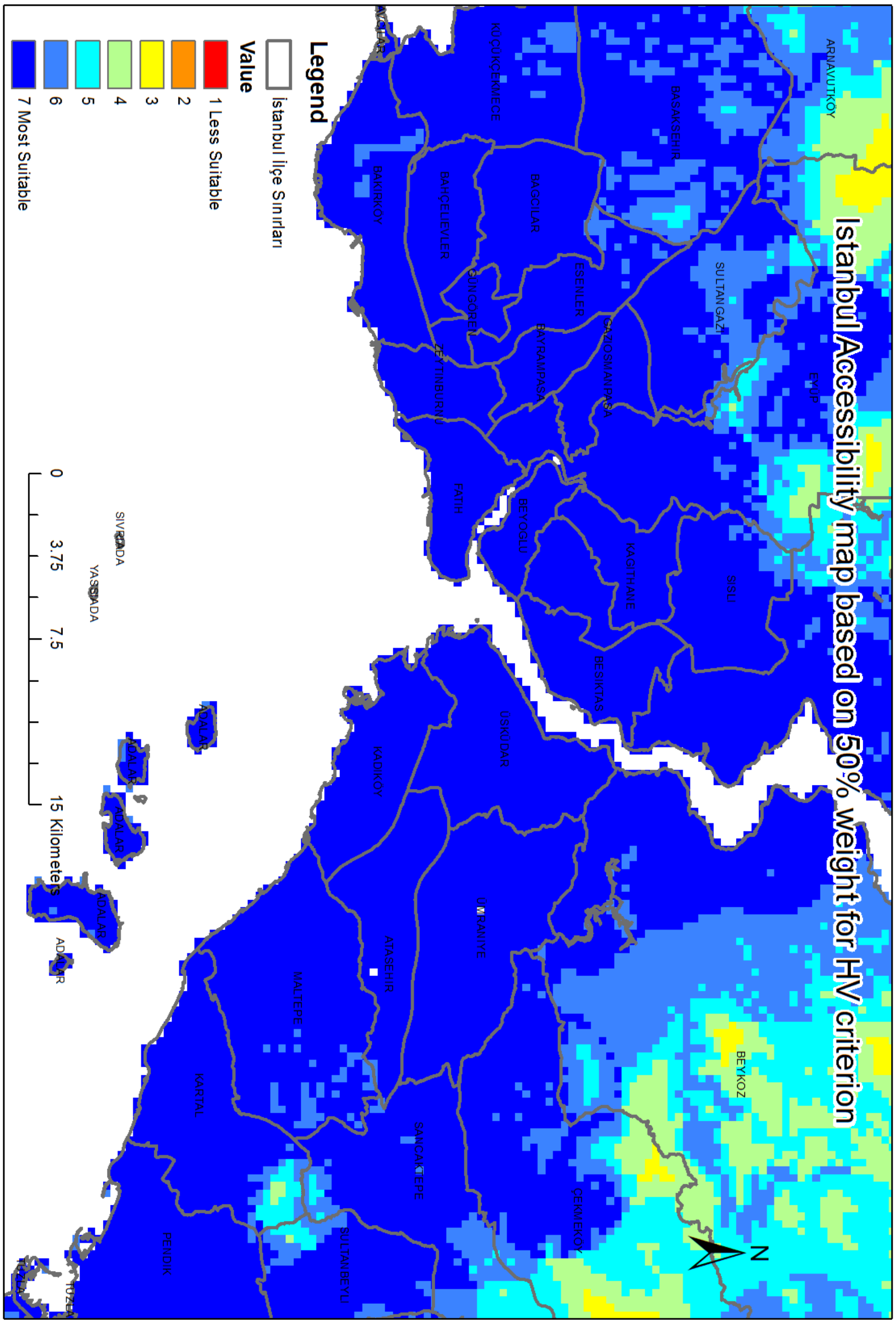

Figure A.81 : Istanbul Accessibility map based on 50% weight for HV criterion

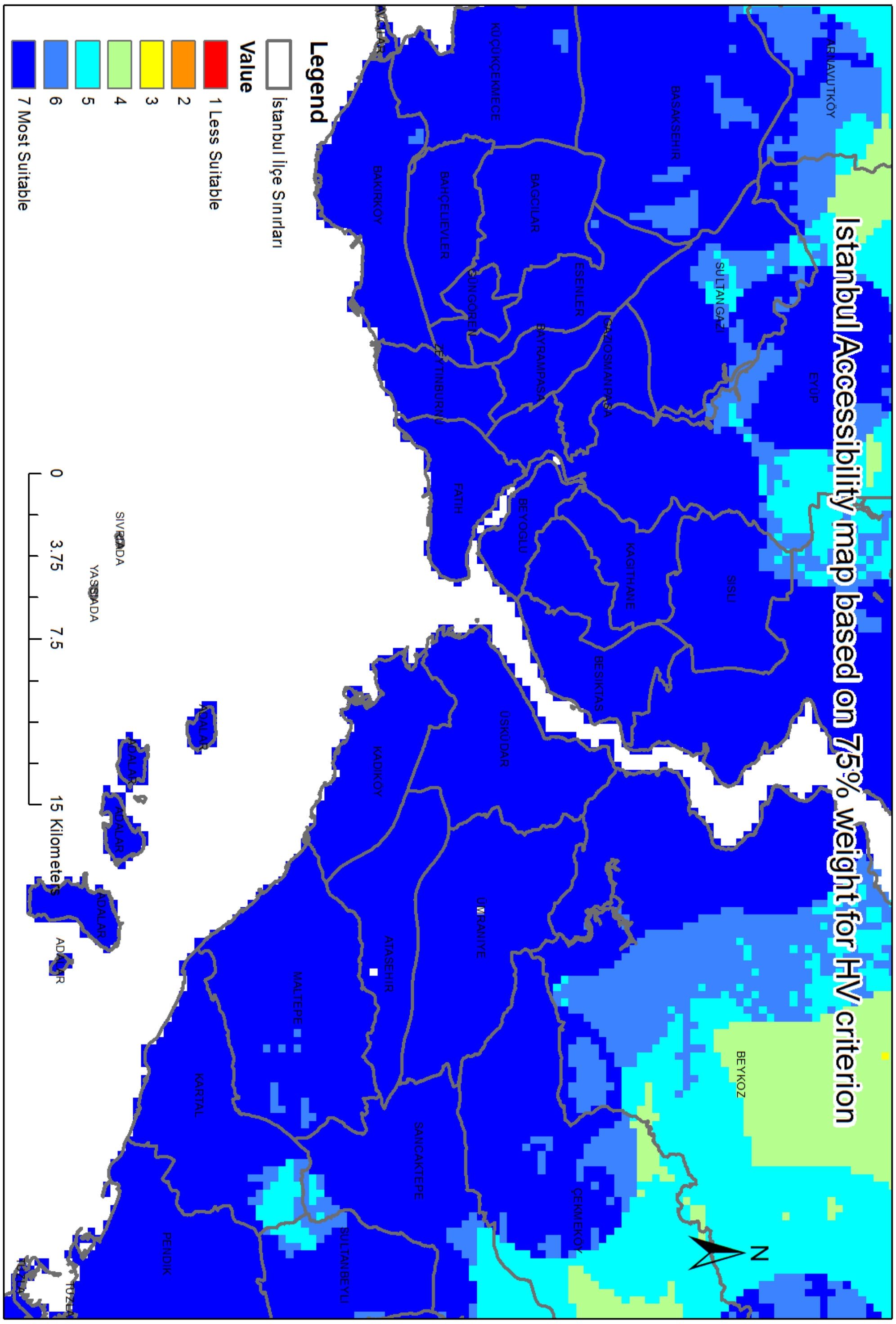

Figure A.82 : Istanbul Accessibility map based on 75% weight for HV criterion

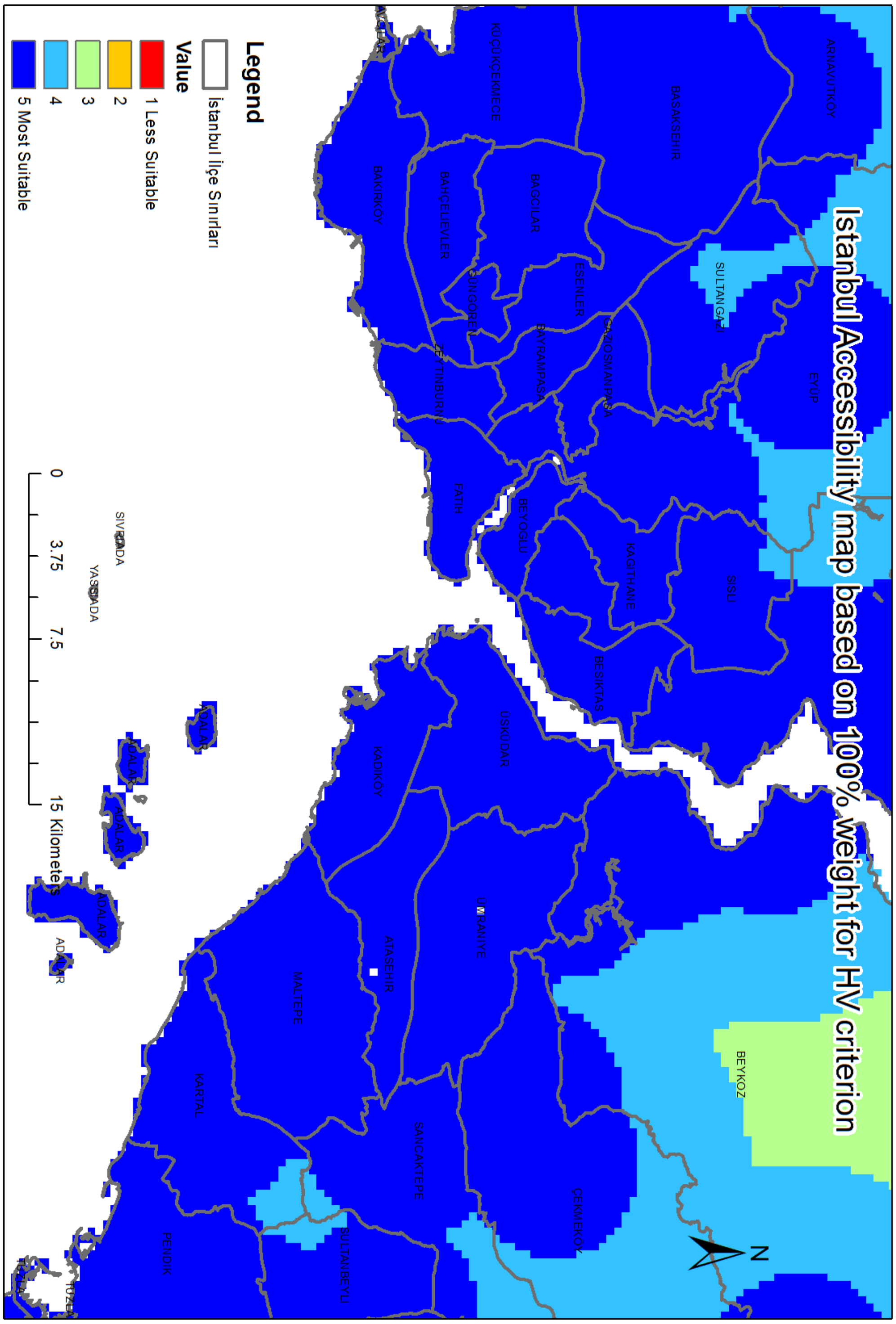

Figure A.83 : Istanbul Accessibility map based on 100% weight for HV criterion

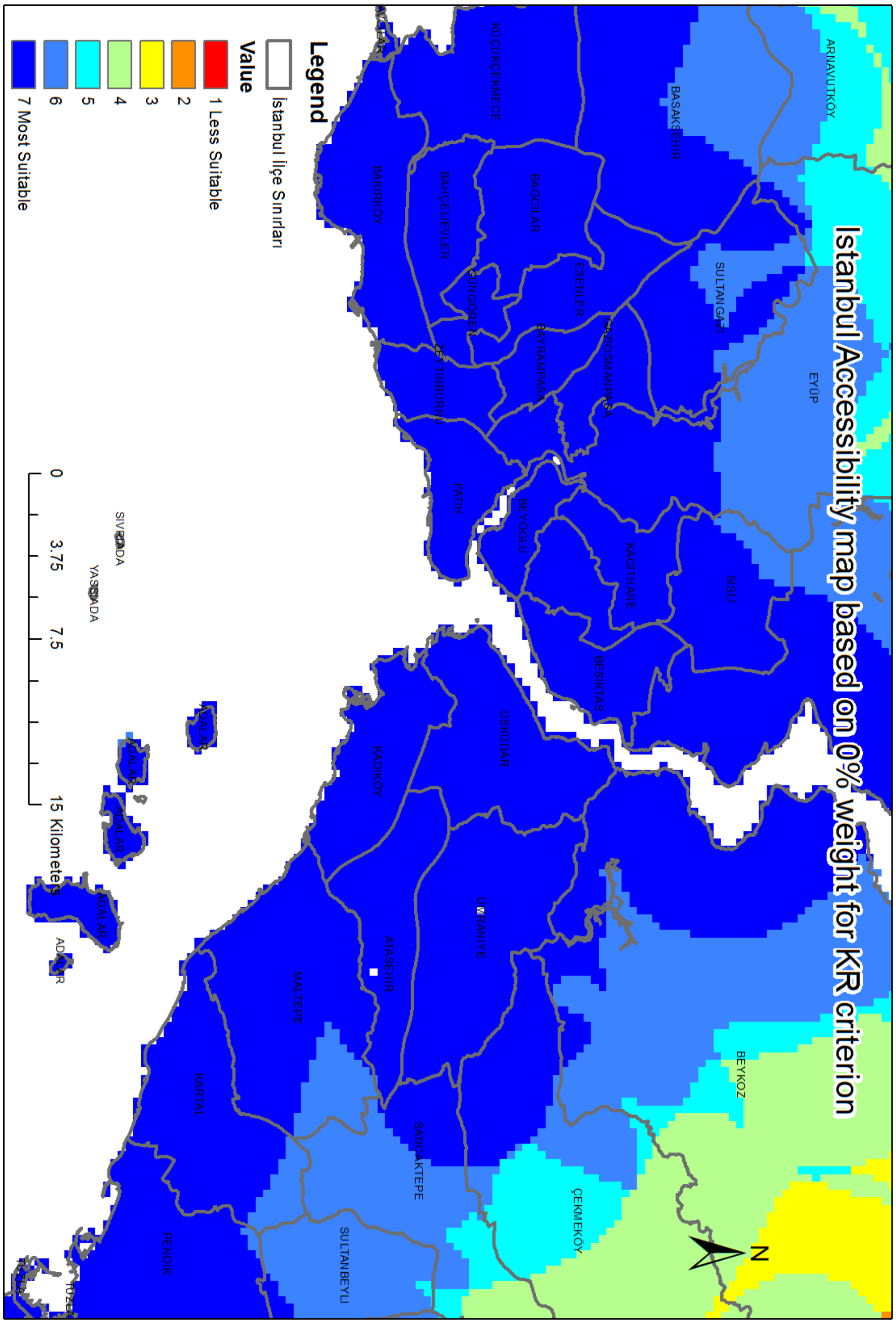

Figure A.84 : Istanbul Accessibility map based on 0% weight for KR criterion

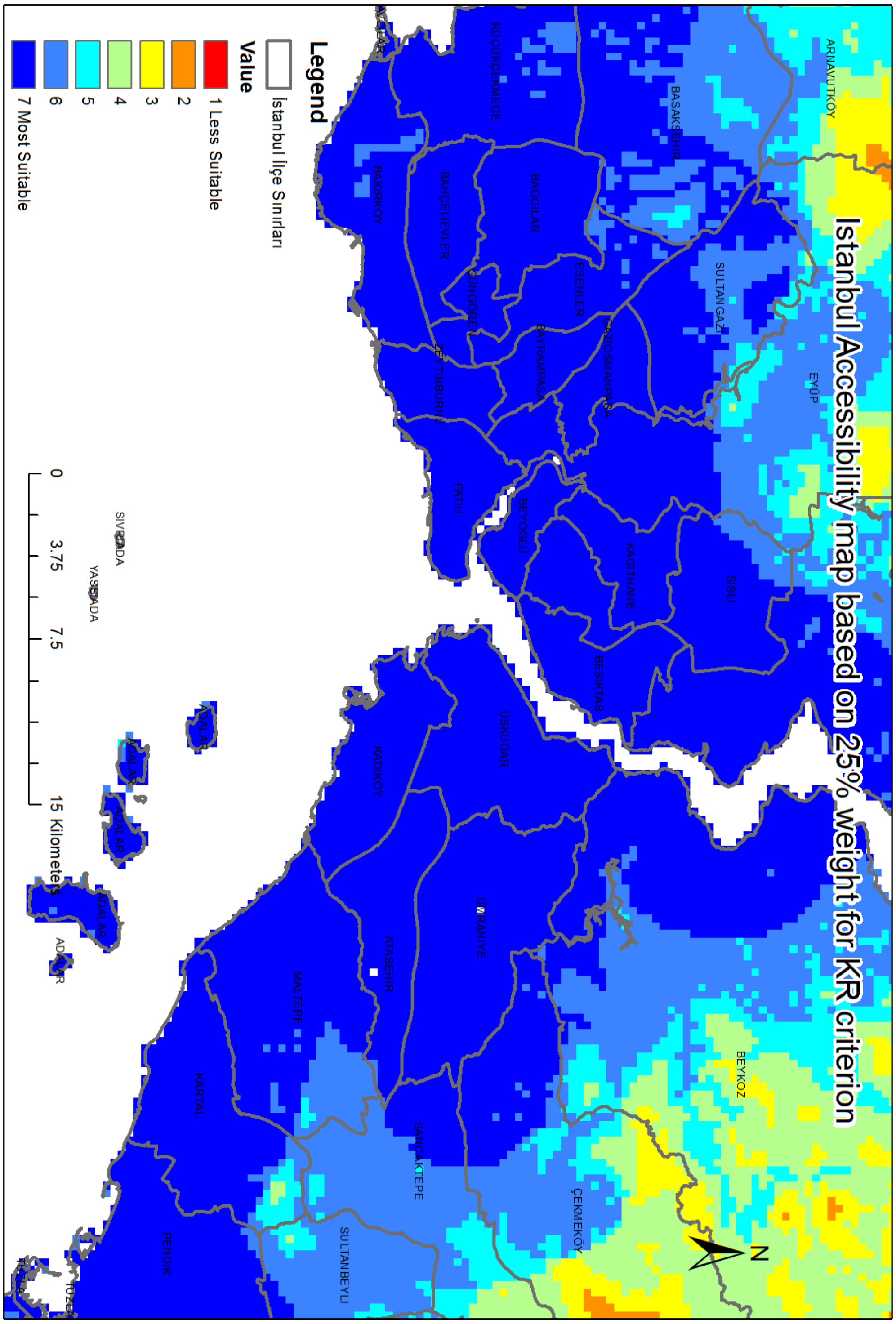

Figure A.85 : Istanbul Accessibility map based on 25% weight for KR criterion

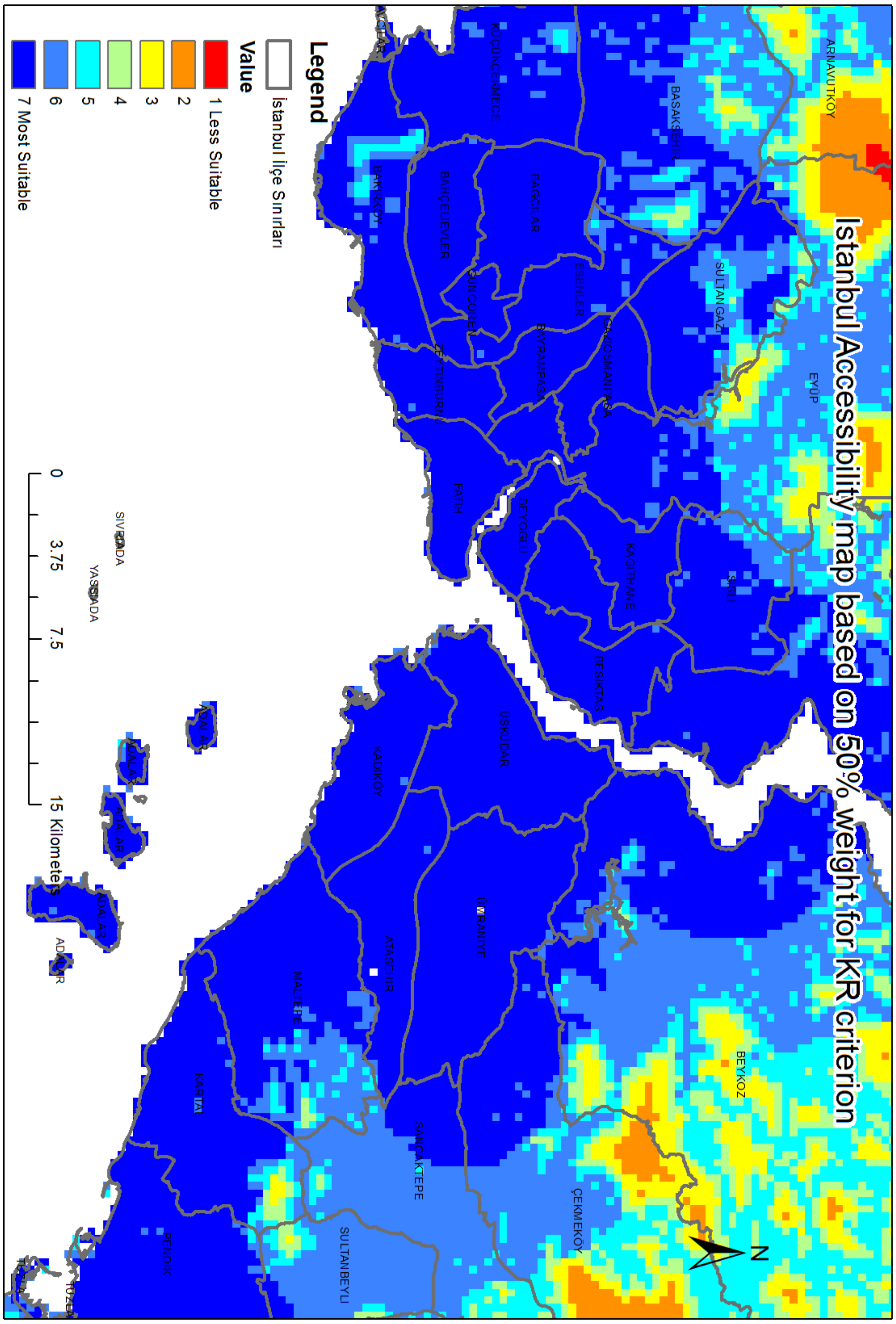

Figure A.86 : Istanbul Accessibility map based on 50% weight for KR criterion

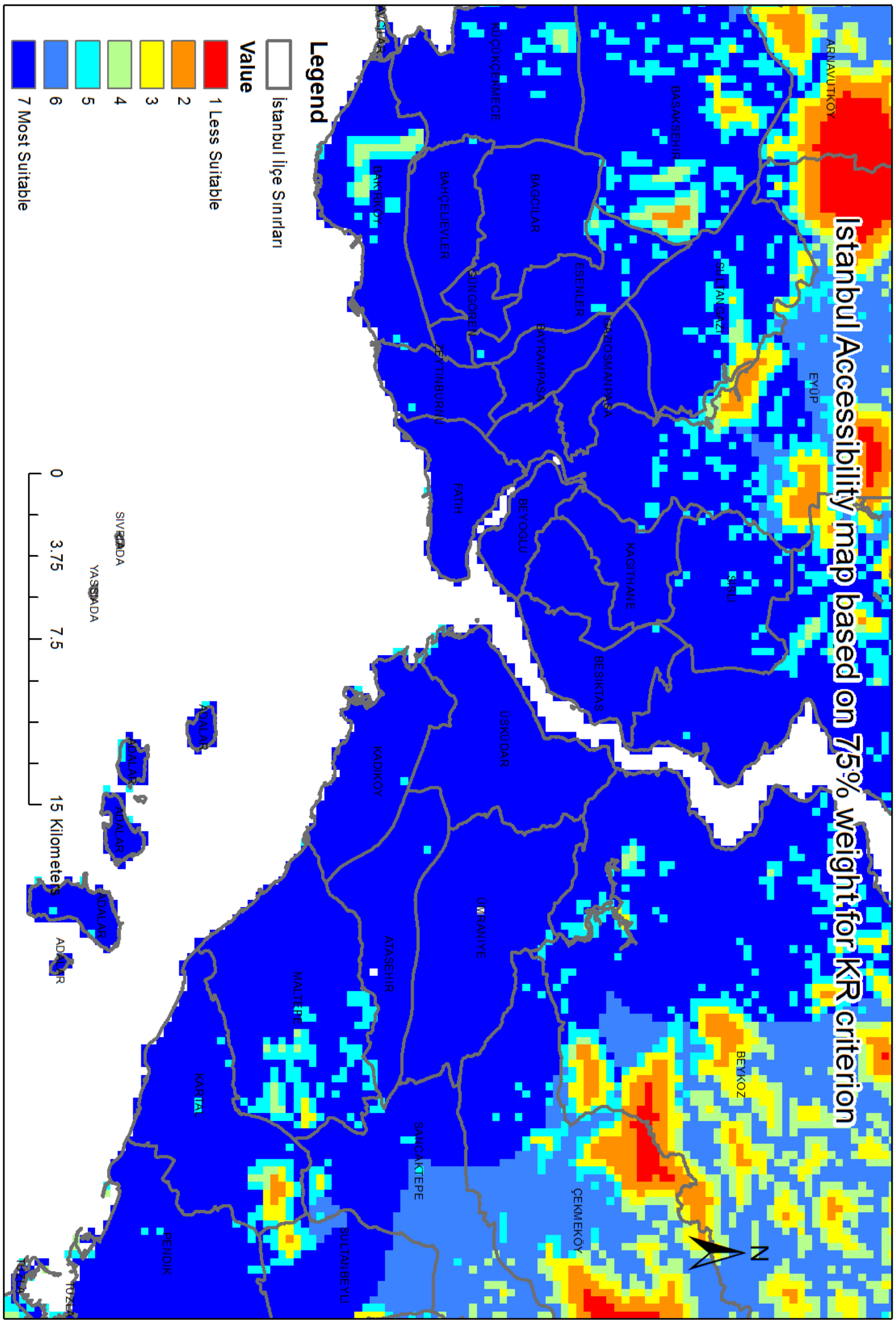

Figure A.87 : Istanbul Accessibility map based on 75% weight for KR criterion

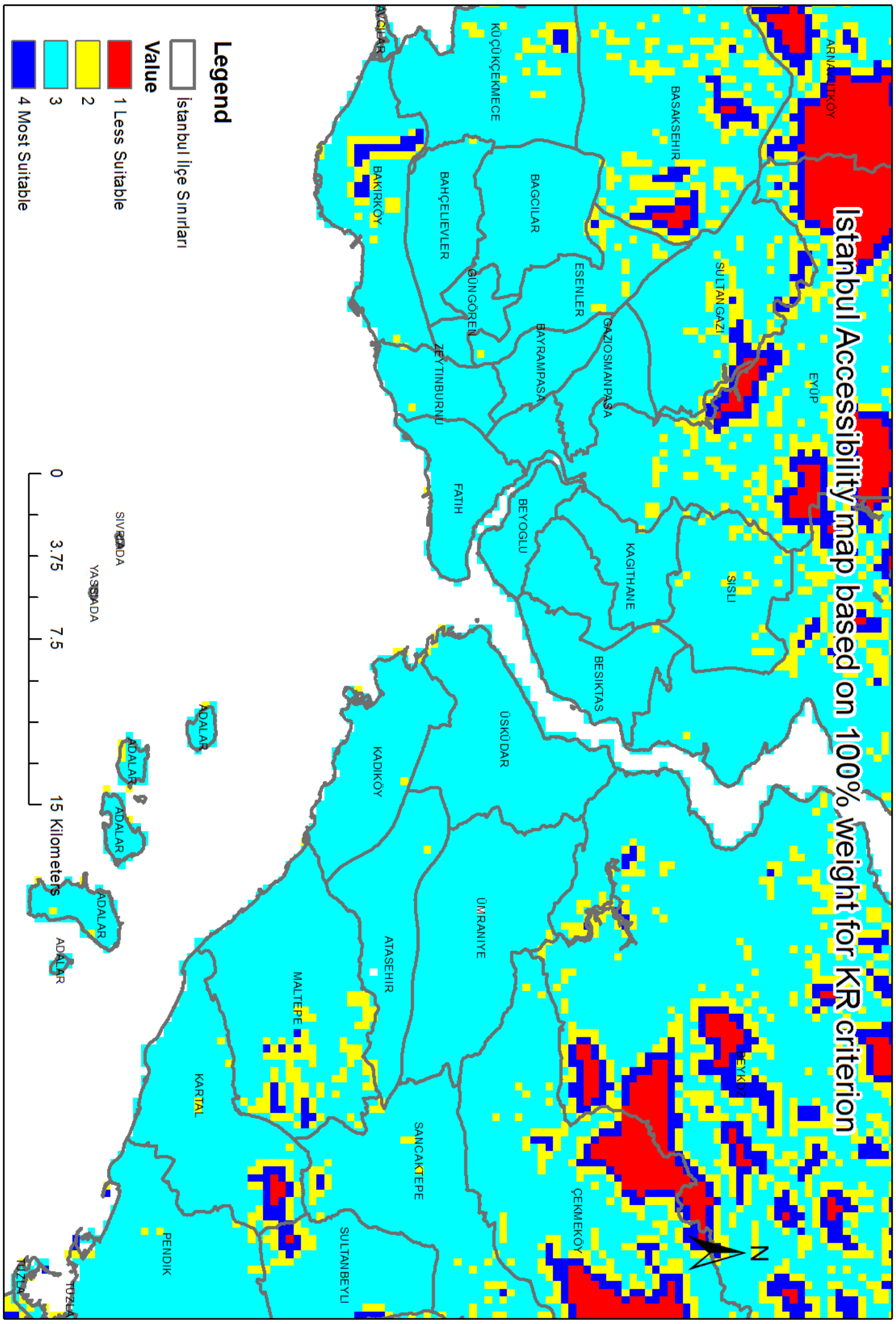

Figure A.88 : Istanbul Accessibility map based on 100% weight for KR criterion

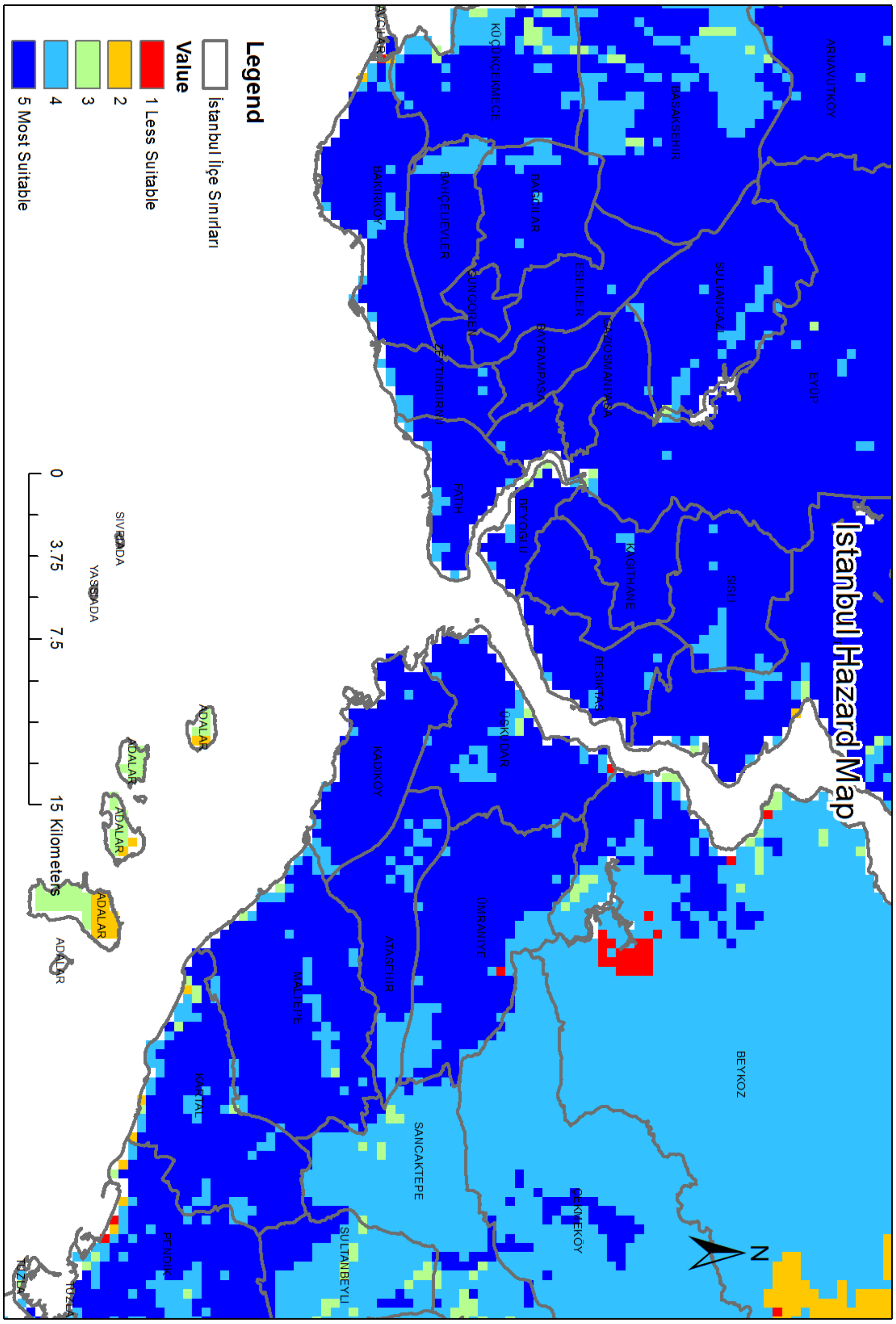

Figure A.89 : Istanbul Hazard Map

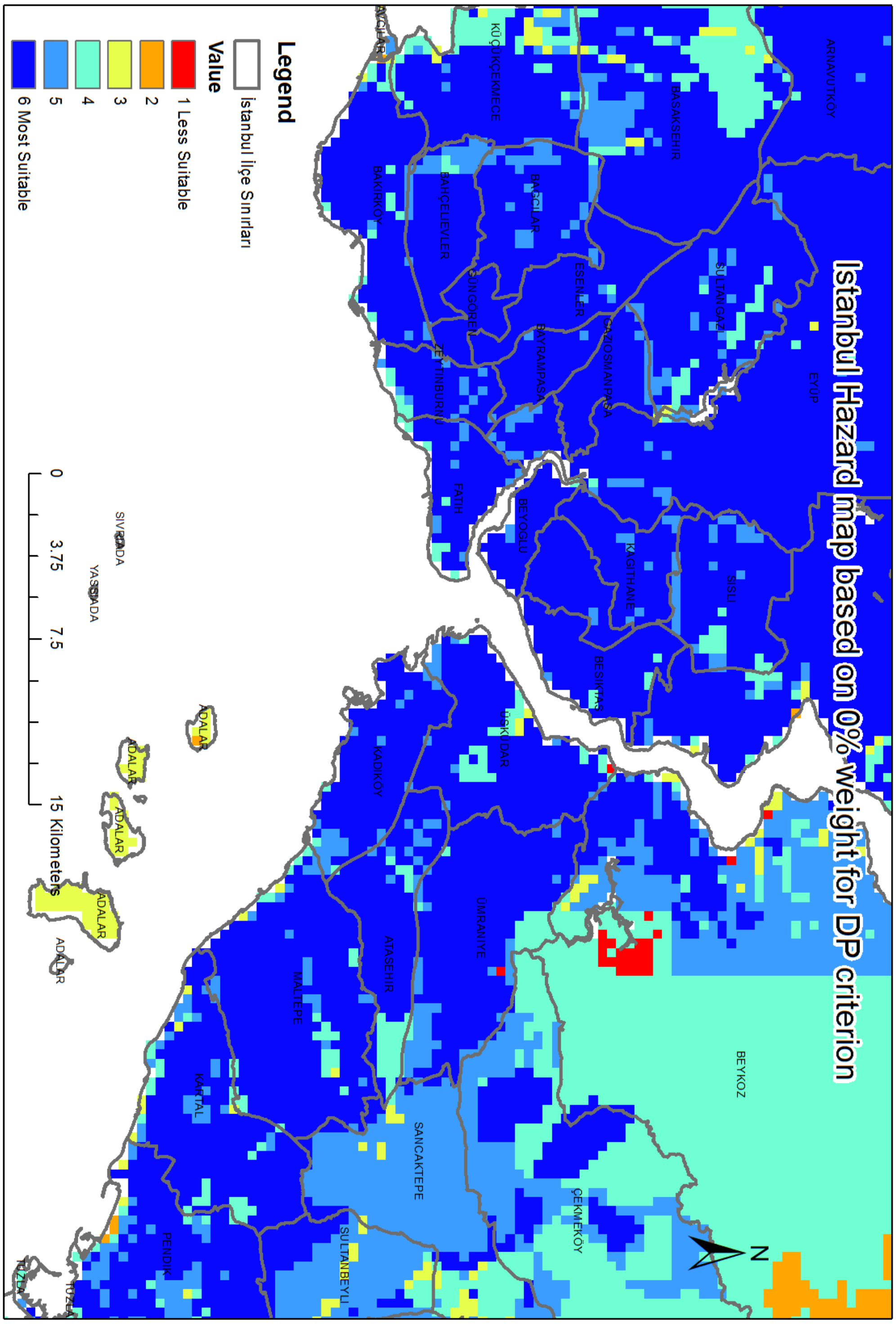

Figure A.90 : Istanbul Hazard map based on 0% weight for DP criterion

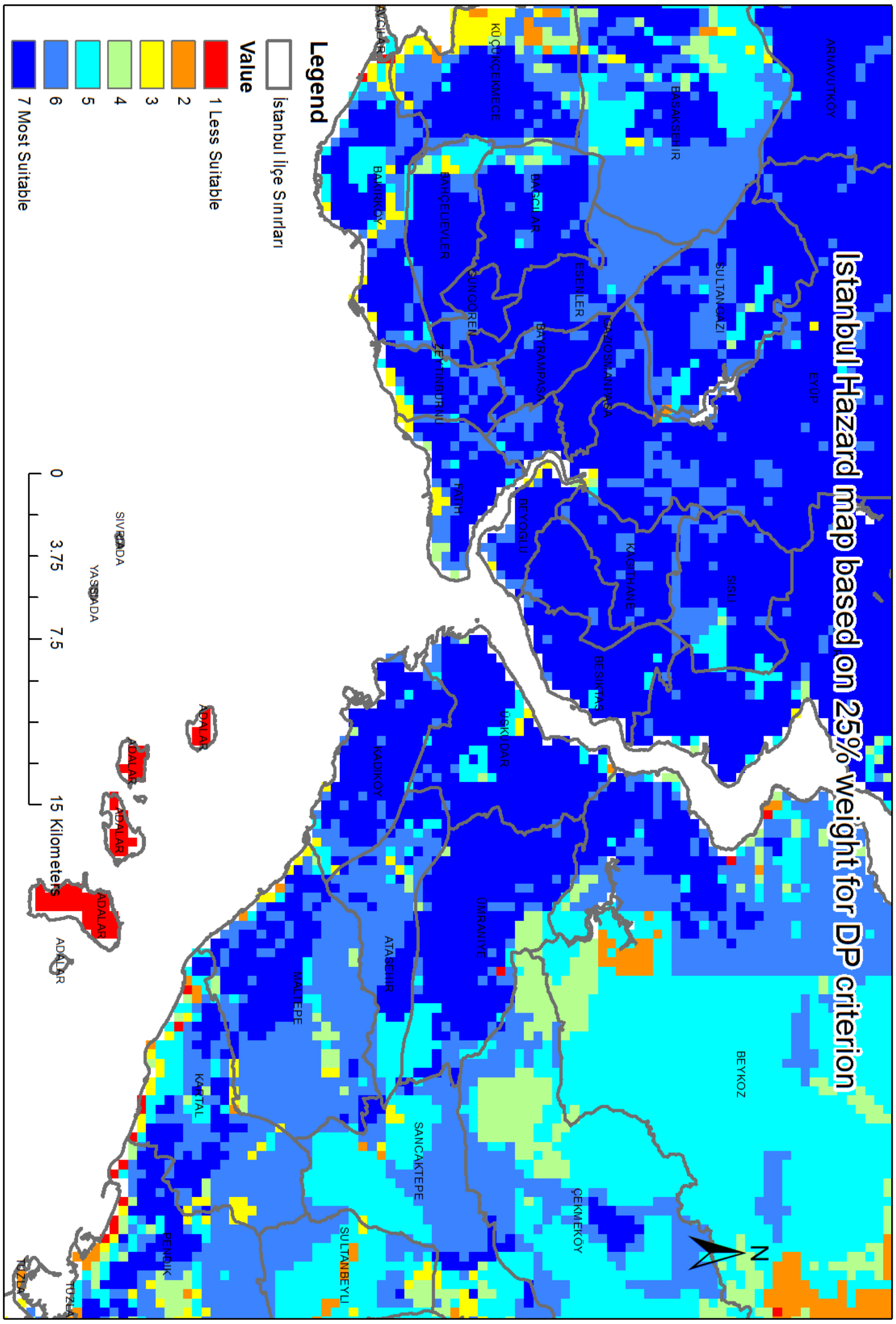

Figure A.91 : Istanbul Hazard map based on 25% weight for DP criterion

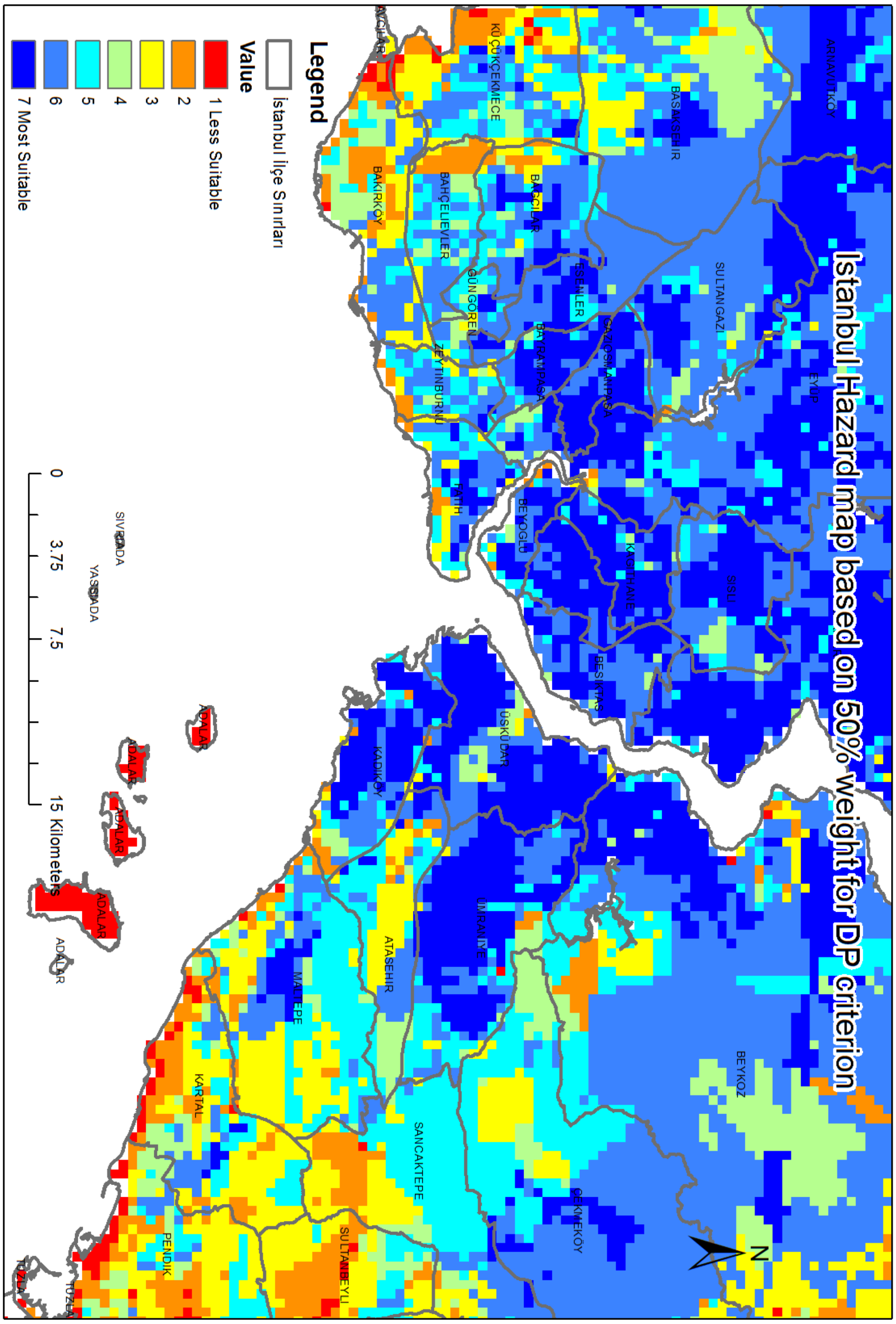

Figure A.92 : Istanbul Hazard map based on 50% weight for DP criterion

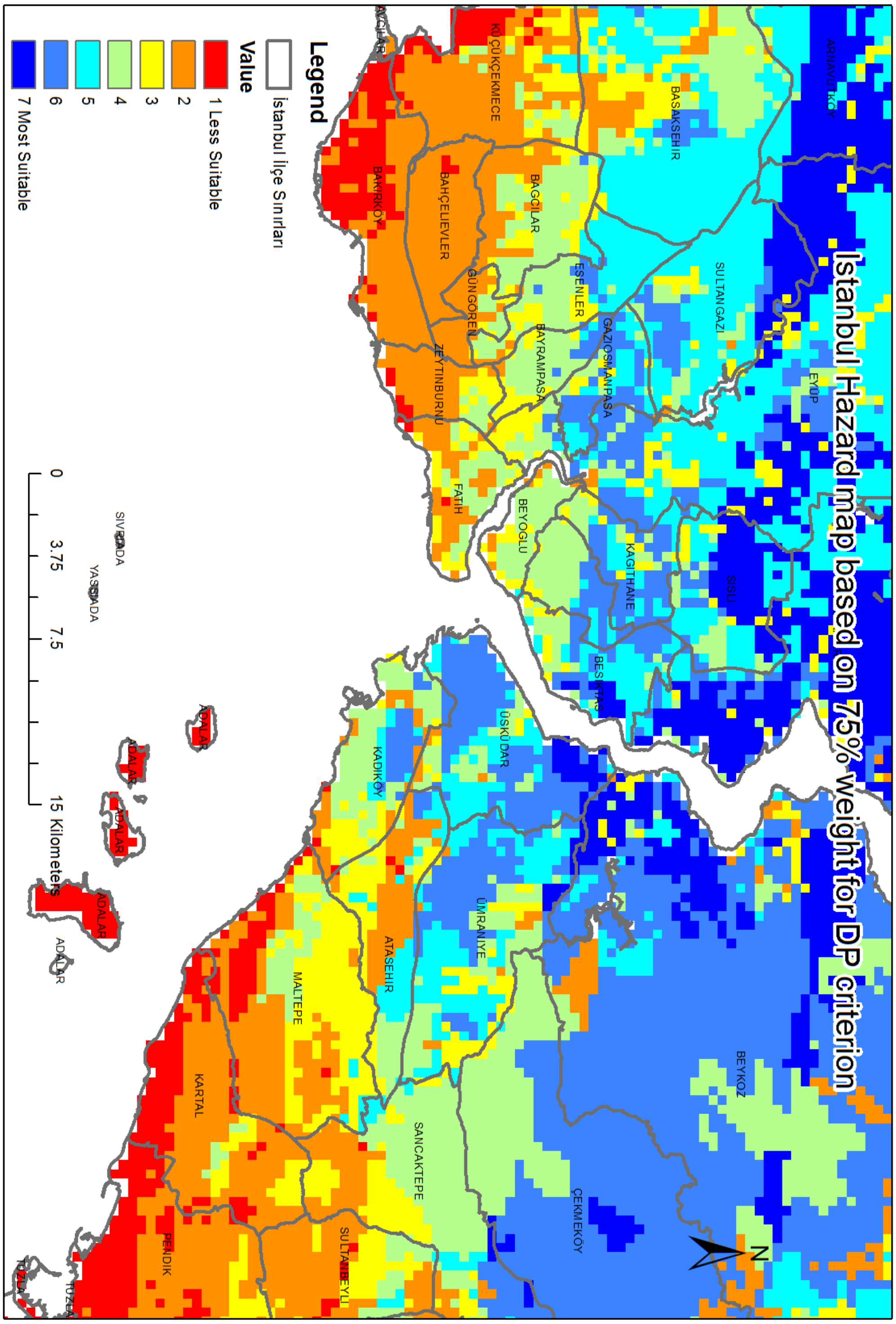

Figure A.93 : Istanbul Hazard map based on 75% weight for DP criterion

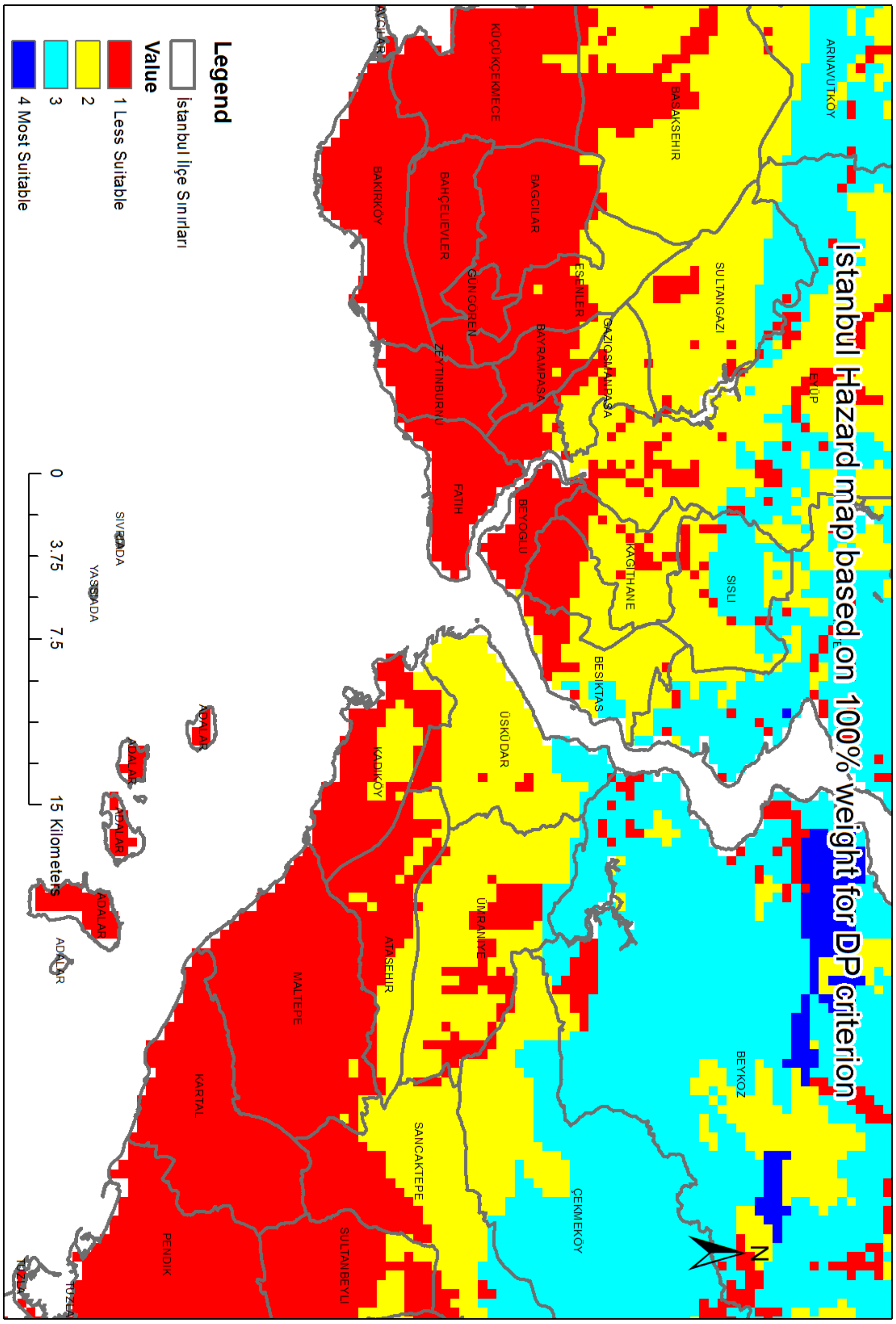

Figure A.94 : Istanbul Hazard map based on 100% weight for DP criterion

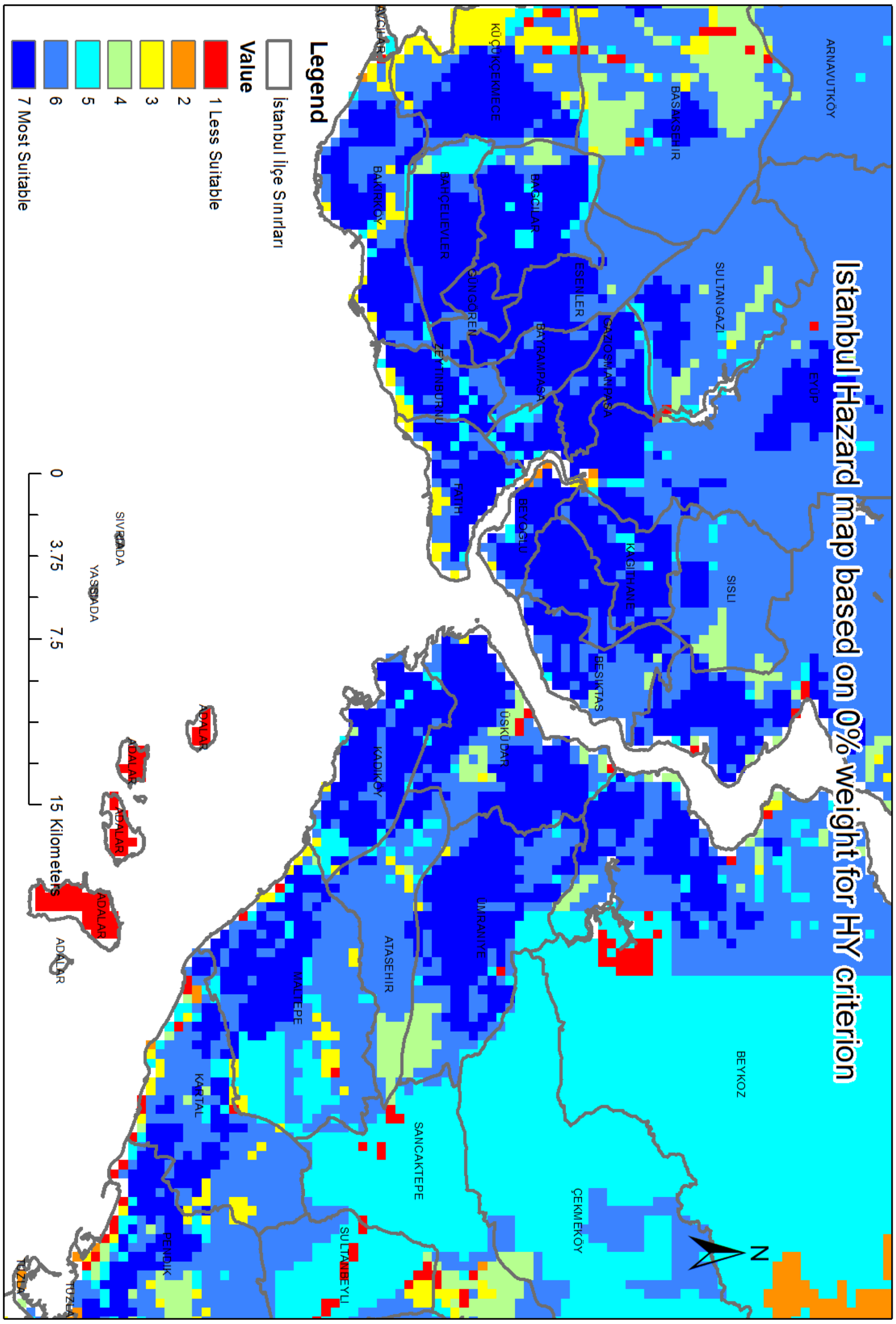

Figure A.95 : Istanbul Hazard map based on 0% weight for HY criterion

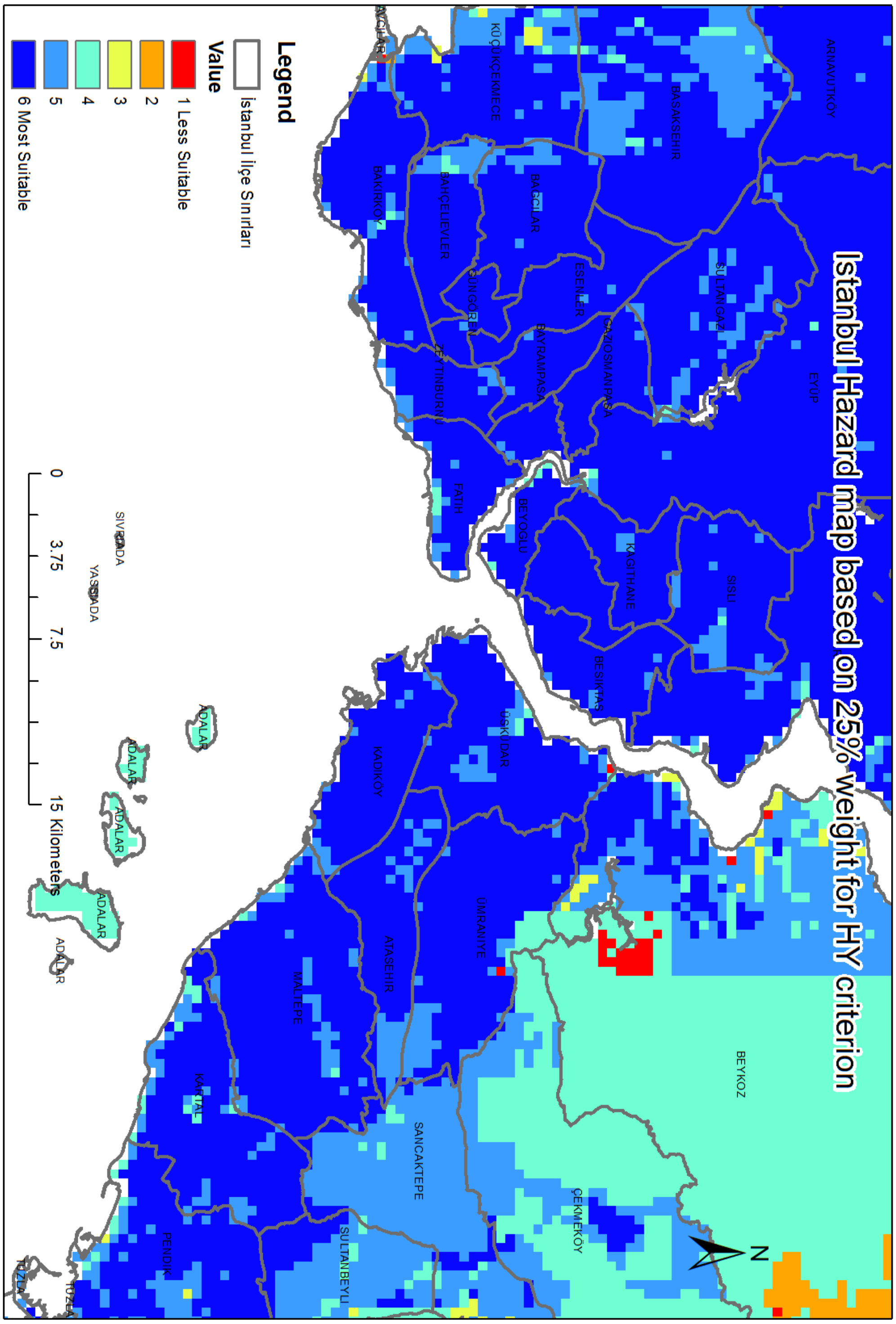

Figure A.96 : Istanbul Hazard map based on 25% weight for HY criterion

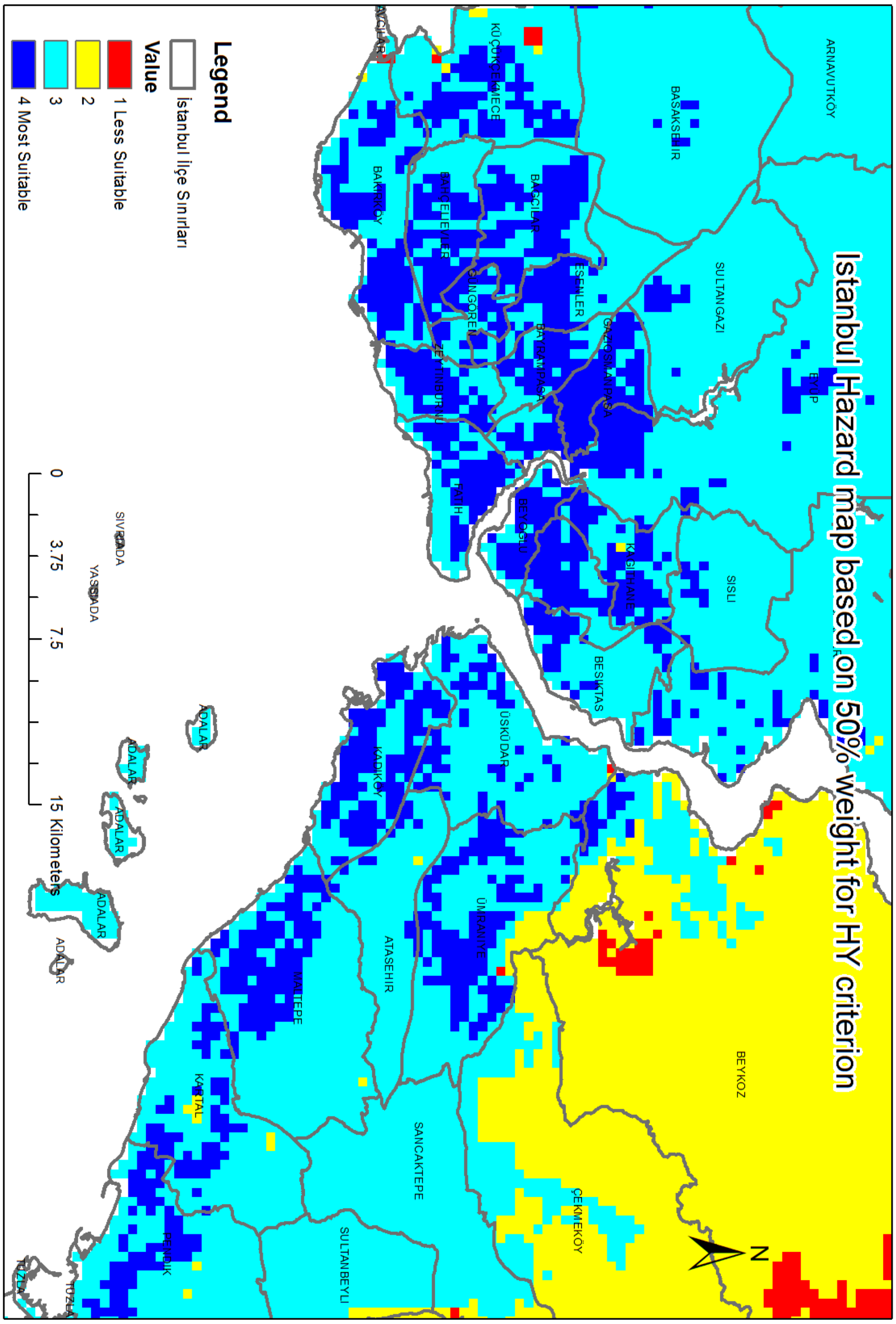

Figure A.97 : Istanbul Hazard map based on 50% weight for HY criterion

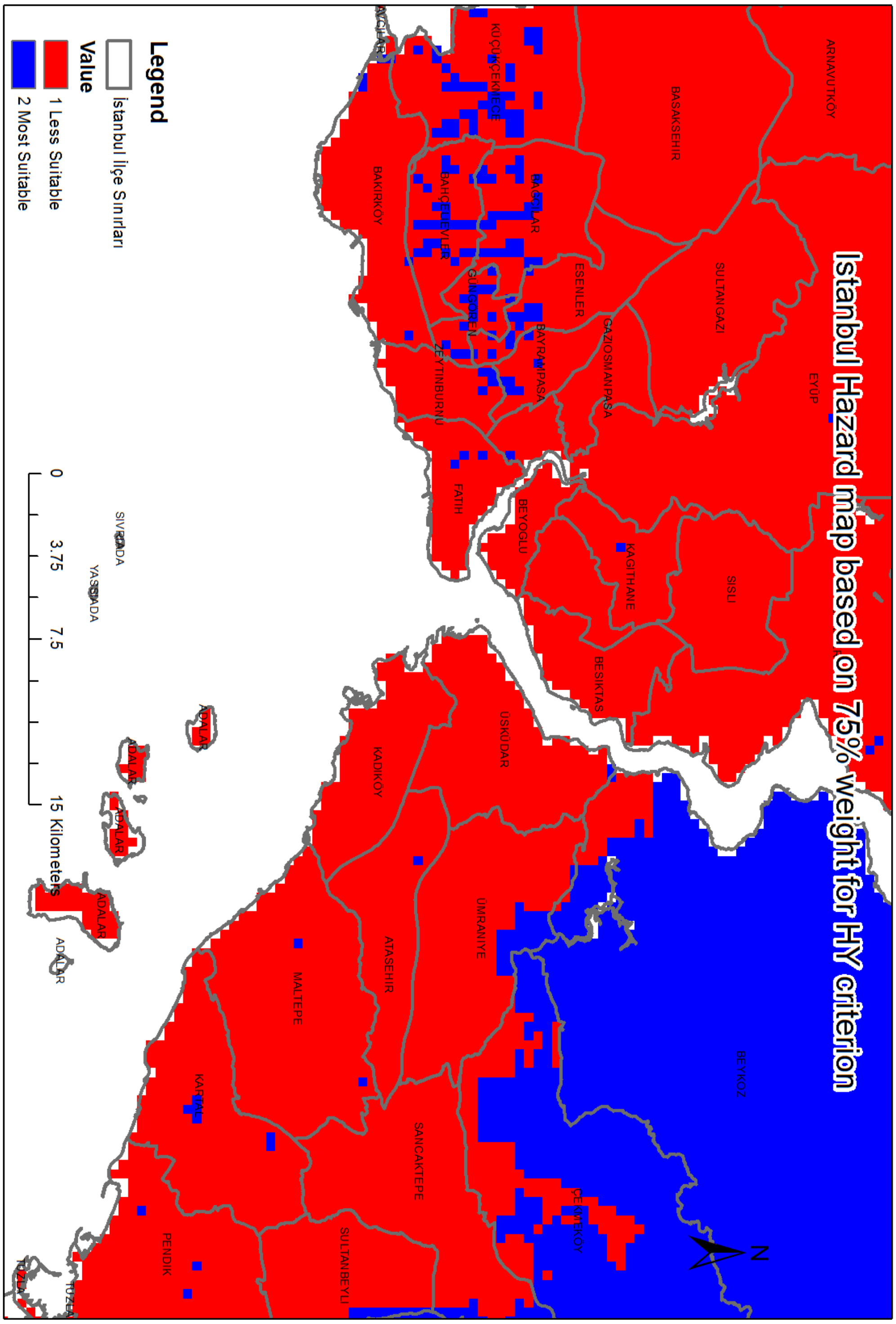

Figure A.98 : Istanbul Hazard map based on 75% weight for HY criterion

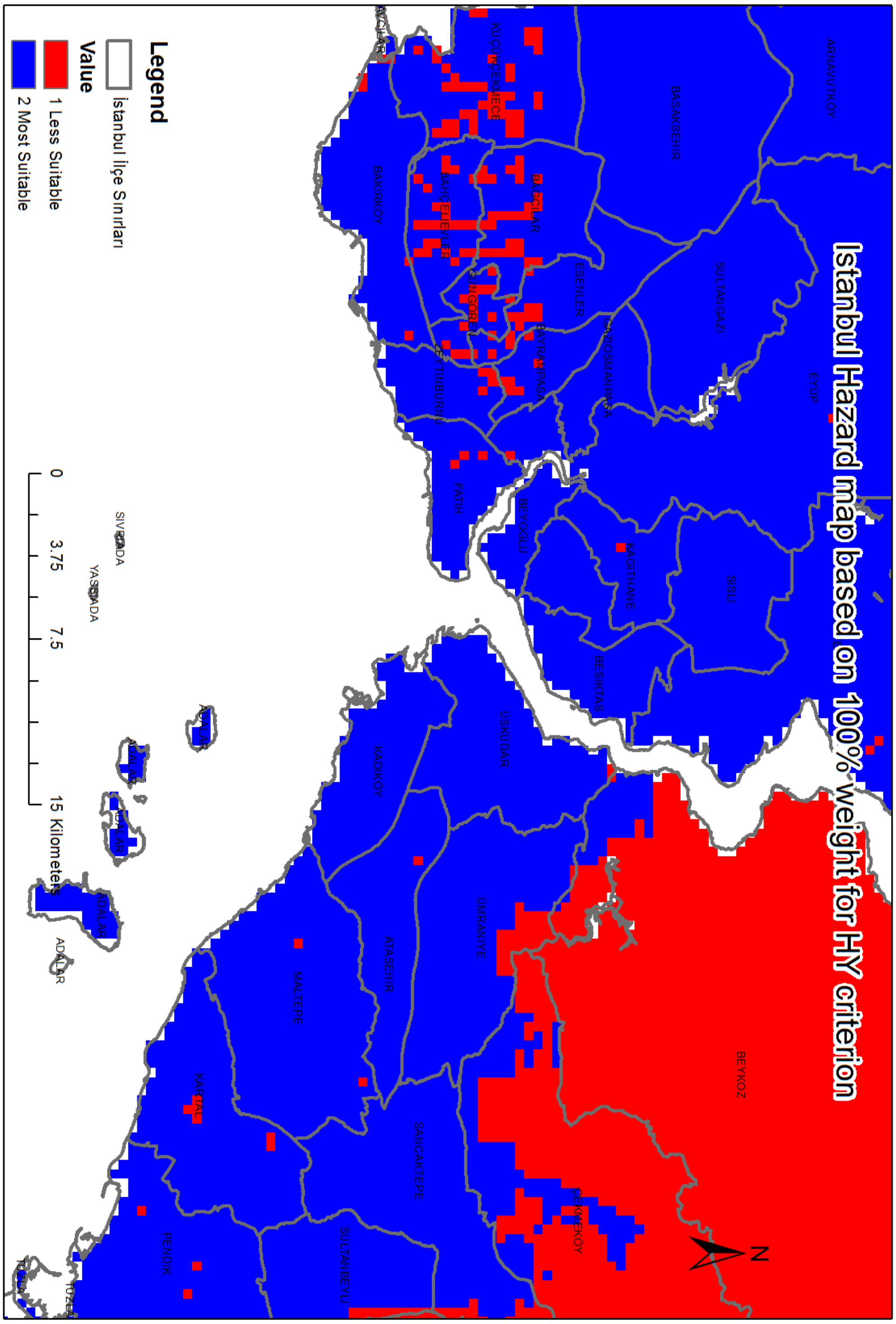

Figure A.99 : Istanbul Hazard map based on 100% weight for HY criterion

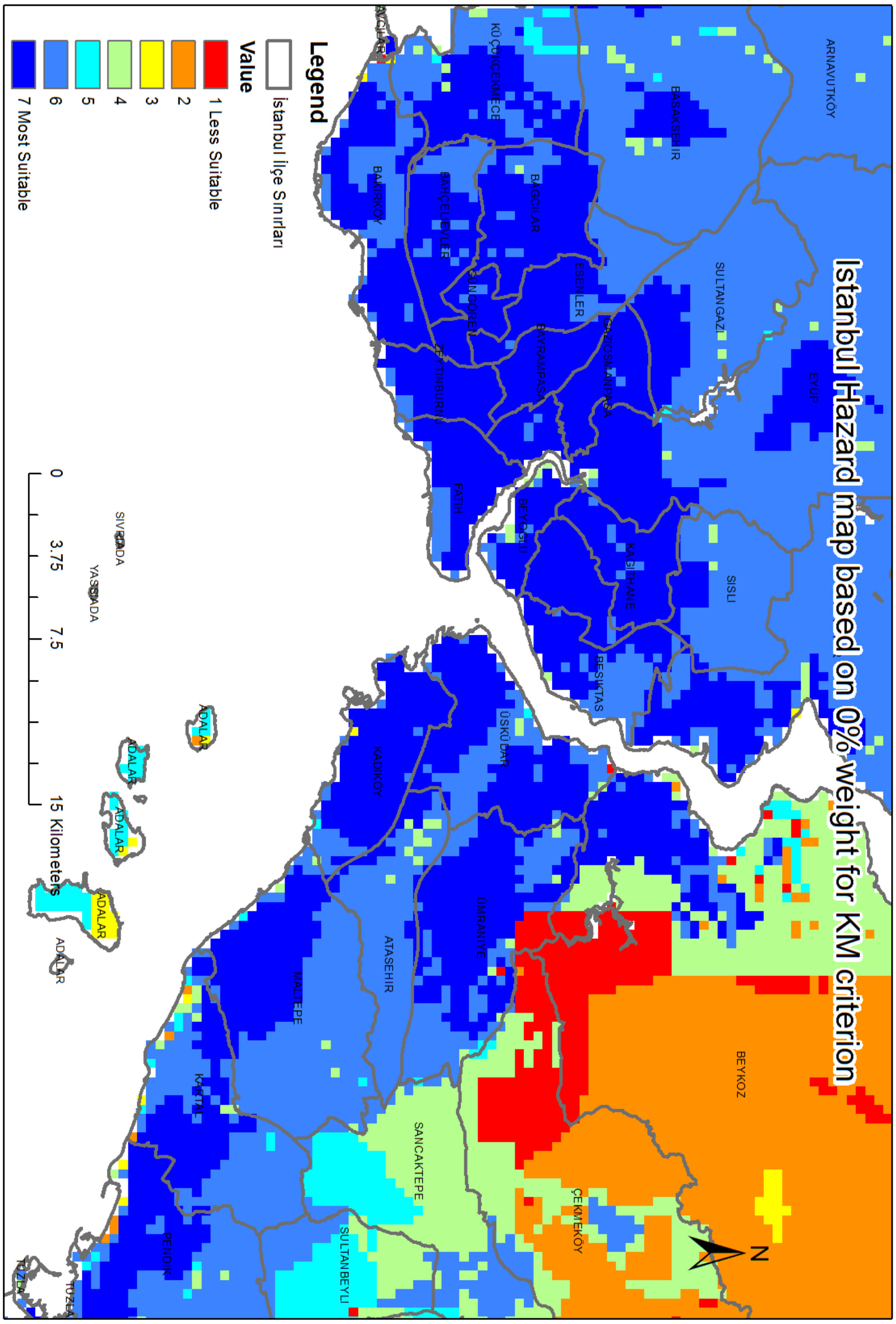

Figure A.100 : Istanbul Hazard map based on 0% weight for KM criterion

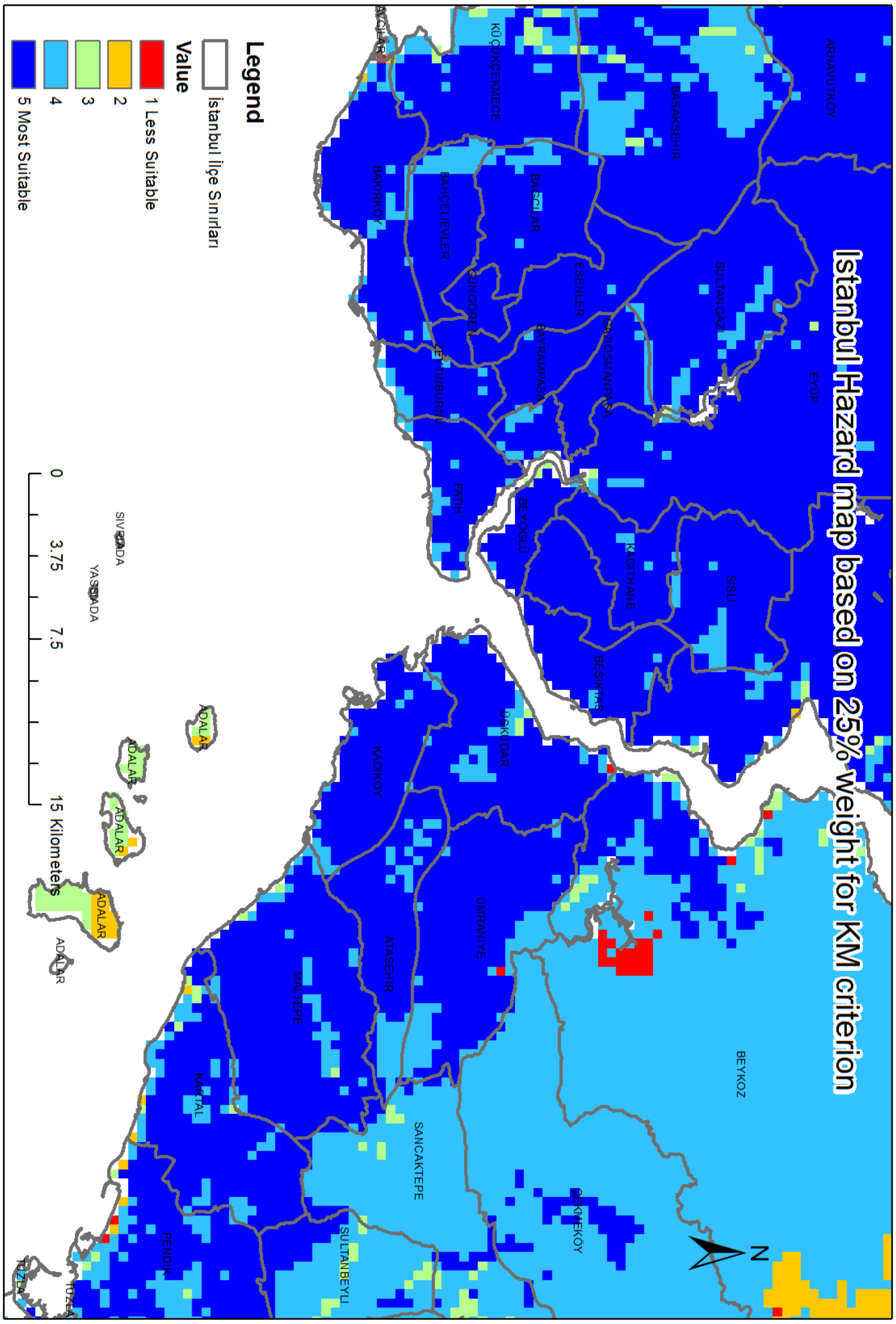

Figure A.101 : Istanbul Hazard map based on 25% weight for KM criterion

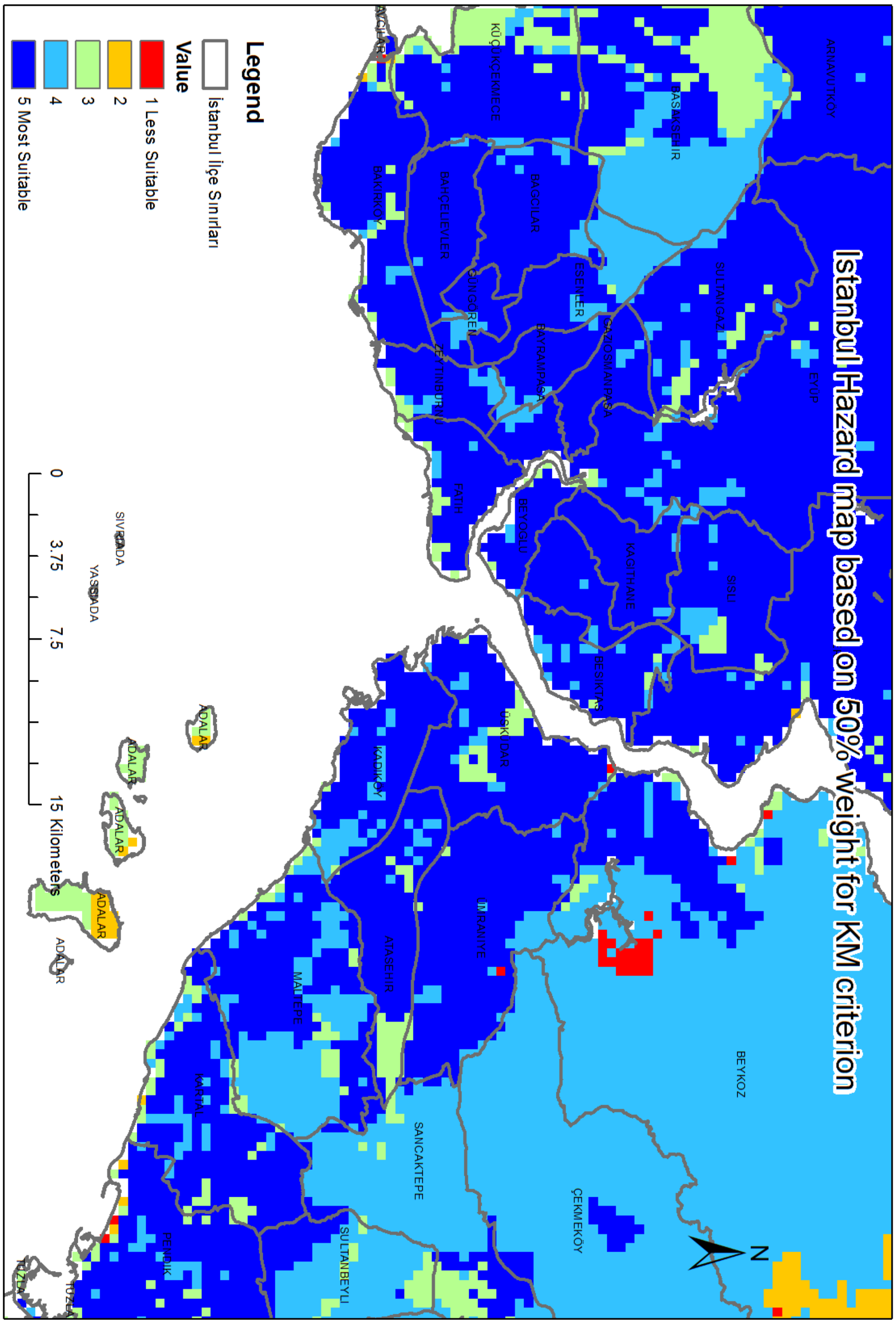

Figure A.102 : Istanbul Hazard map based on 50% weight for KM criterion

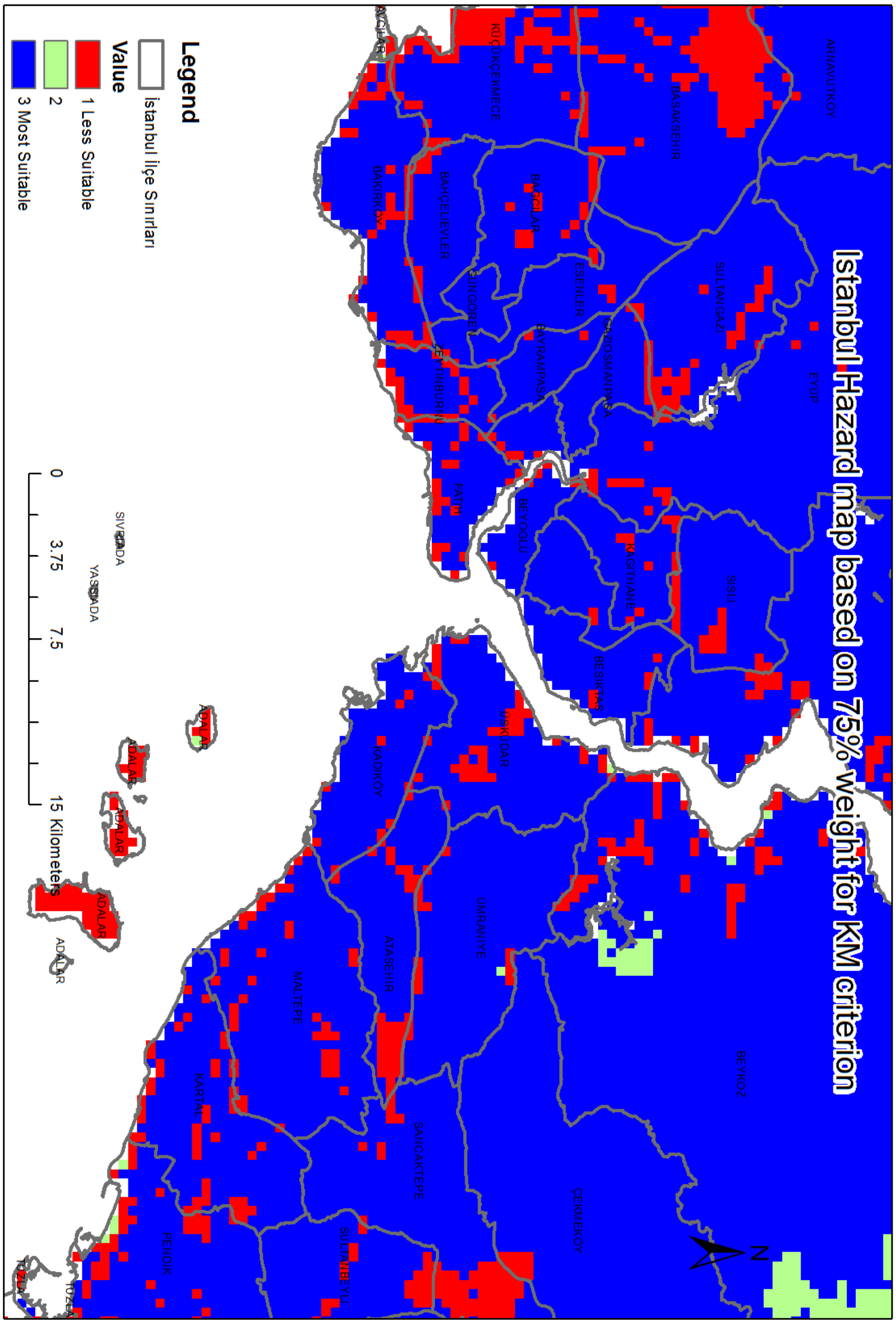

Figure A.103 : Istanbul Hazard map based on 75% weight for KM criterion

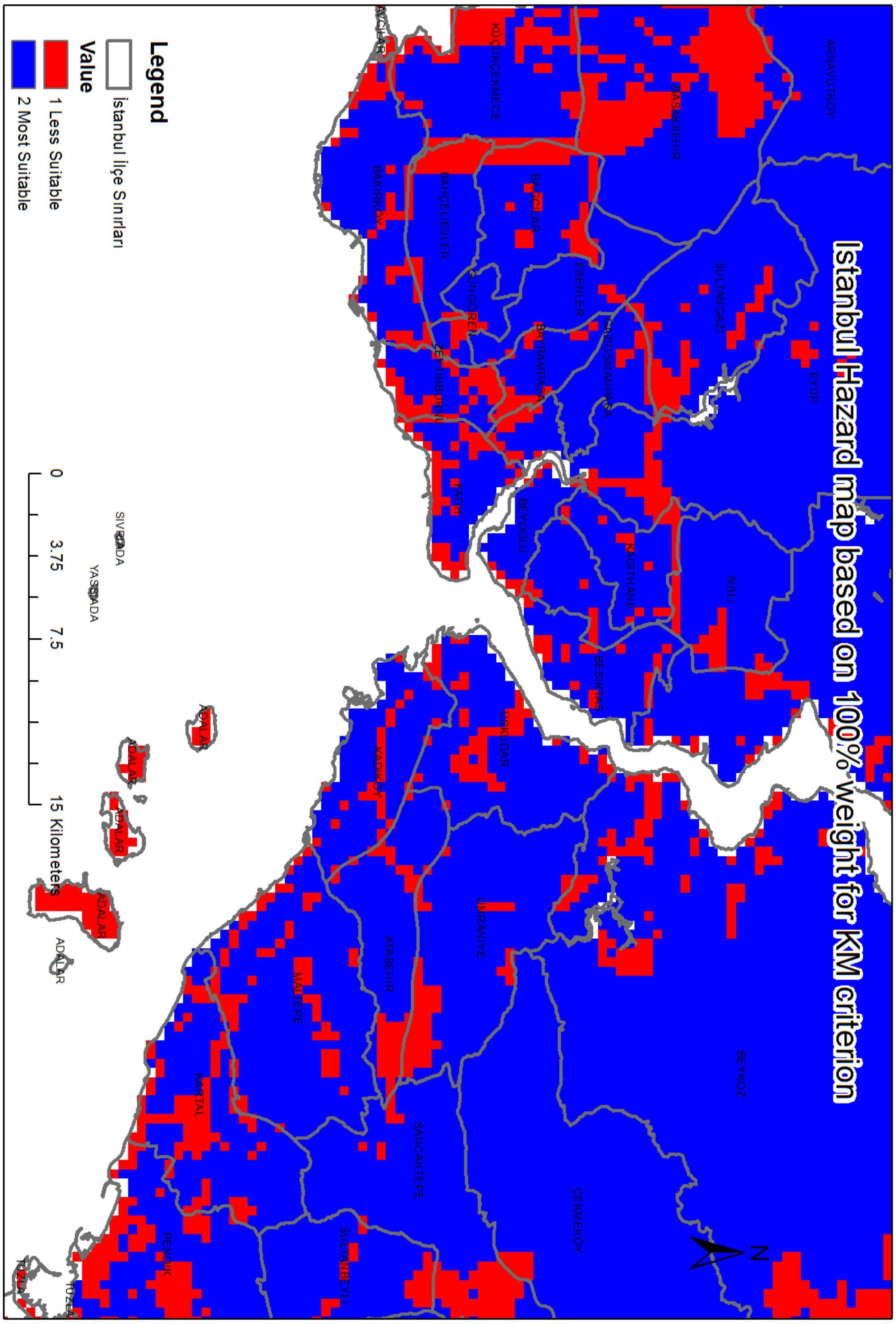

Figure A.104 : Istanbul Hazard map based on 100% weight for KM criterion

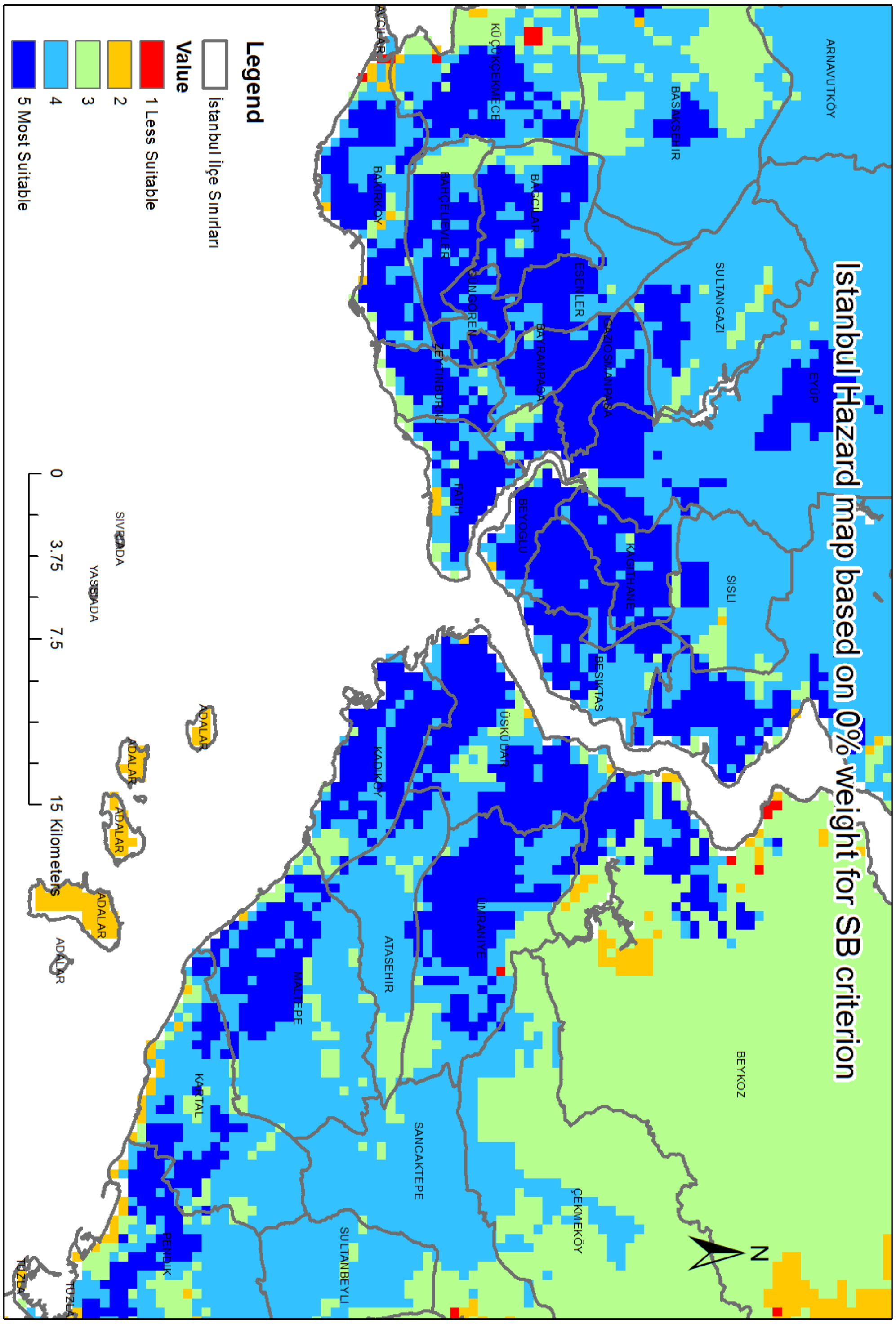

Figure A.105 : Istanbul Hazard map based on 0% weight for SB criterion

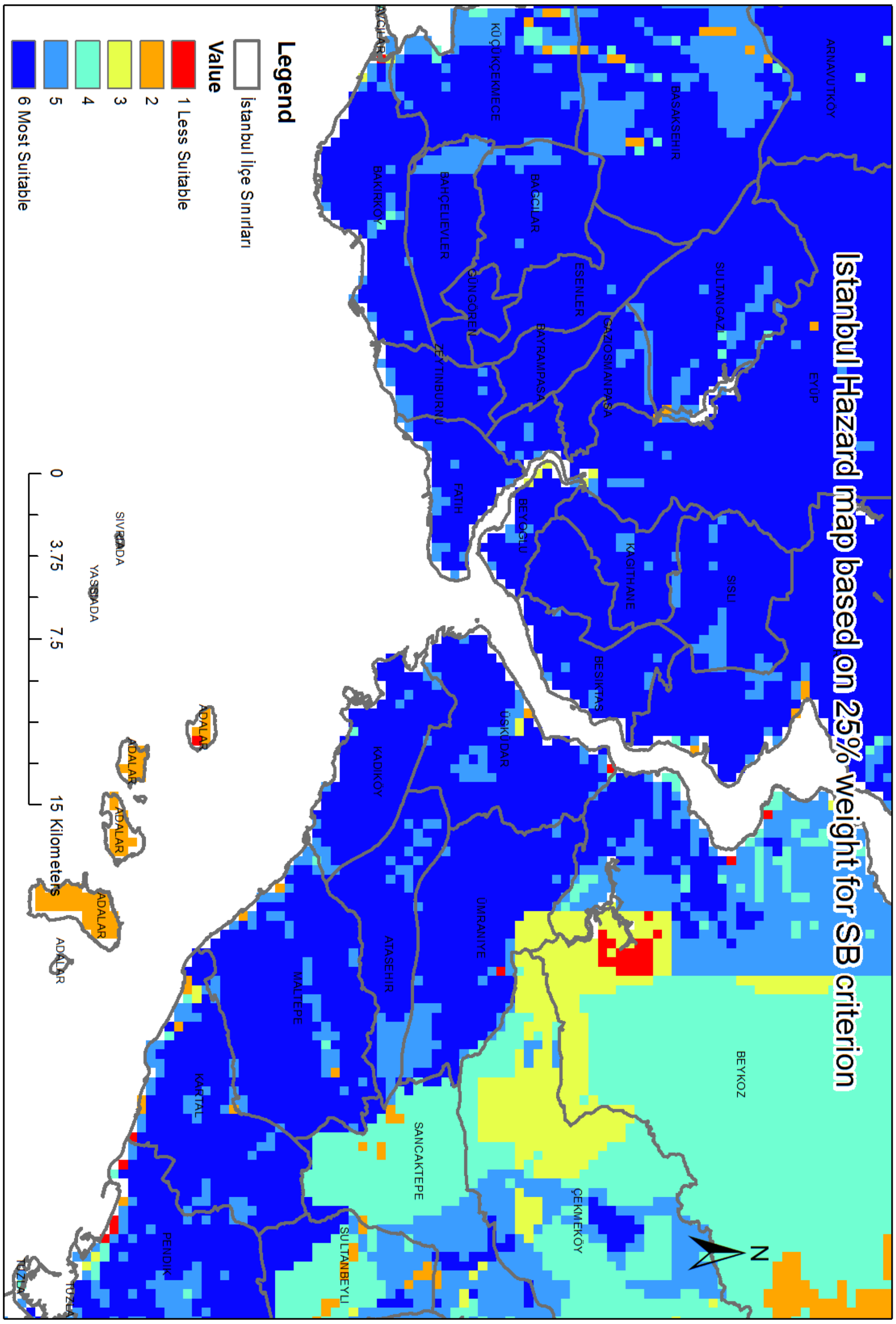

Figure A.106 : Istanbul Hazard map based on 25% weight for SB criterion

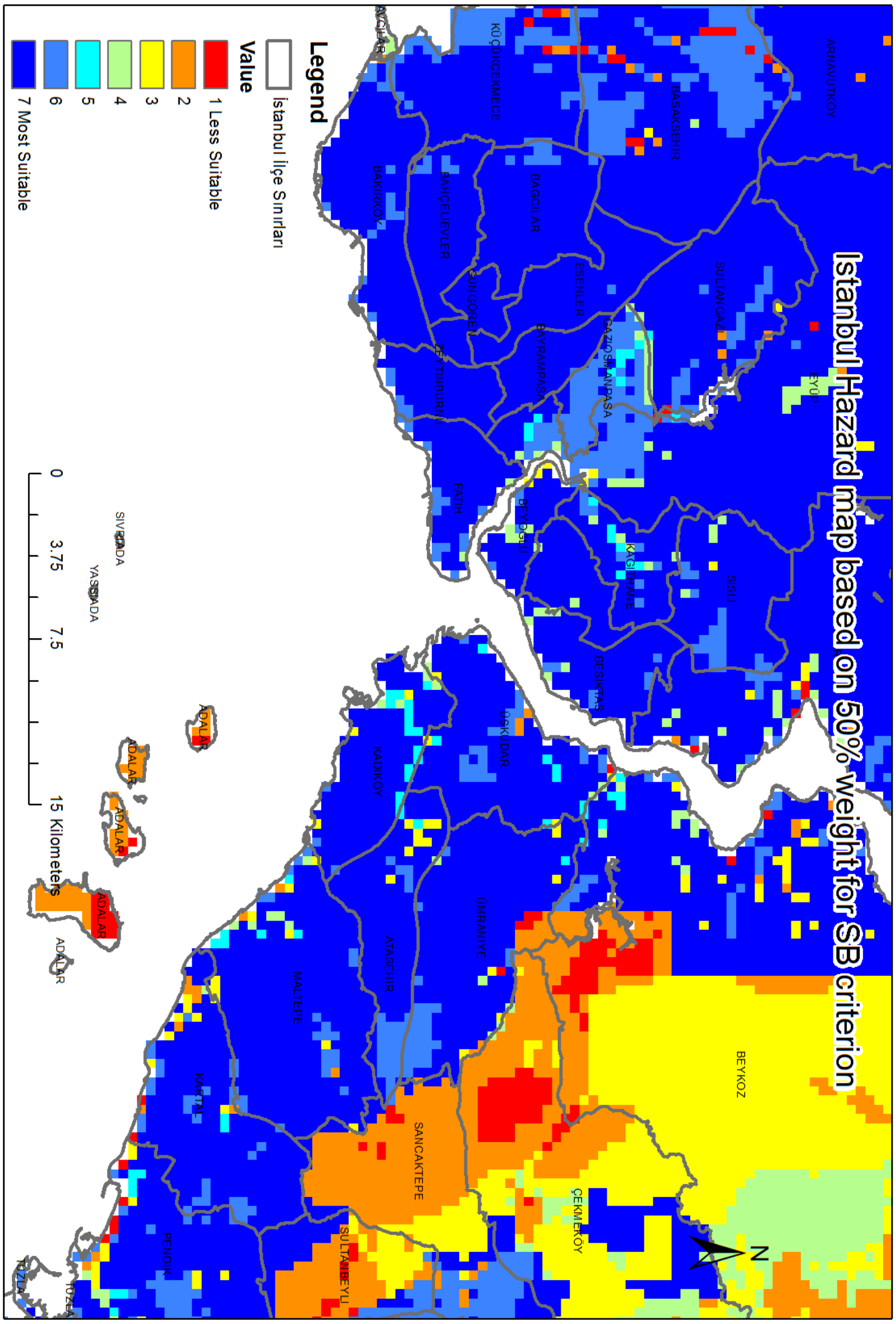

Figure A.107 : Istanbul Hazard map based on 50% weight for SB criterion

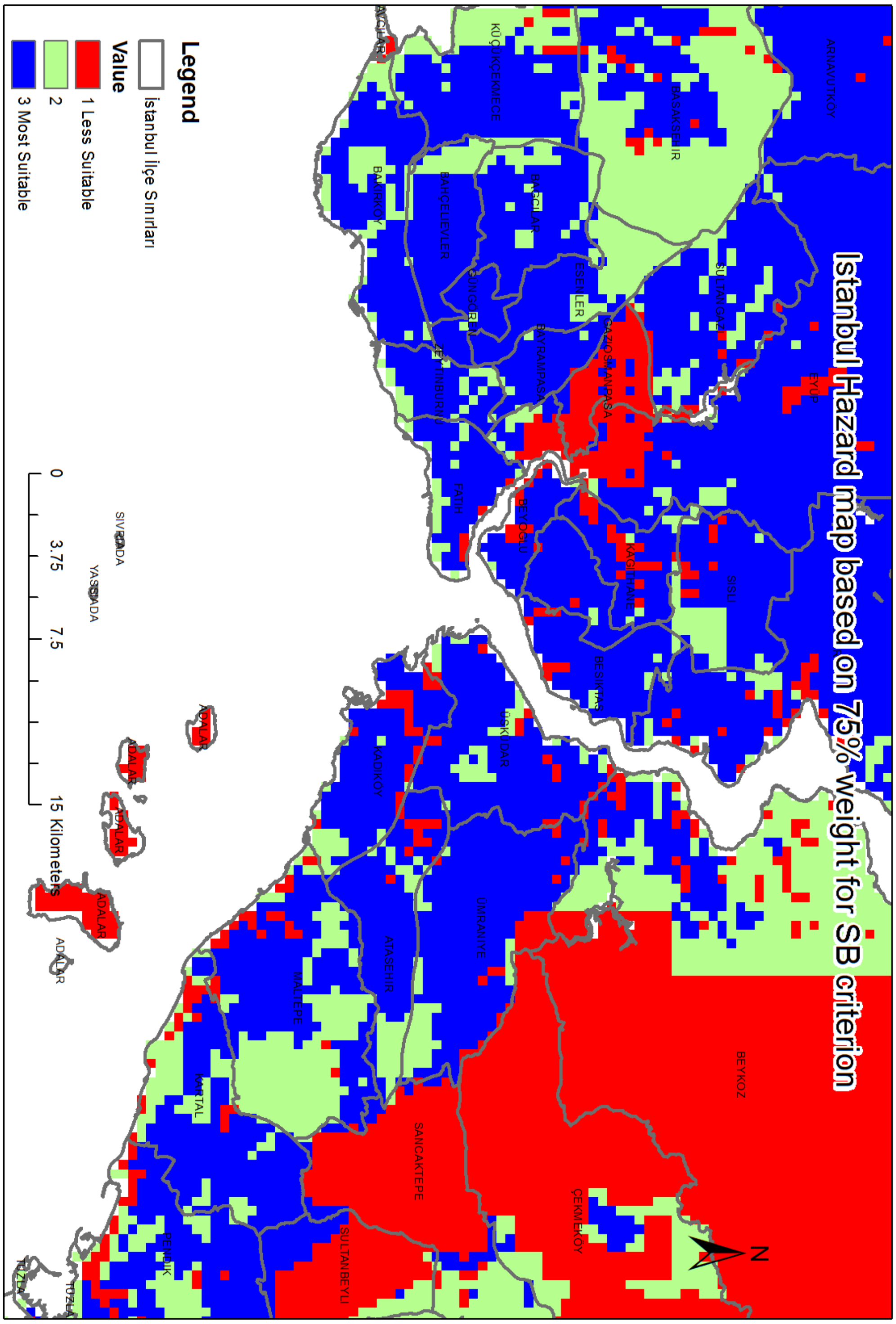

Figure A.108 : Istanbul Hazard map based on 75% weight for SB criterion

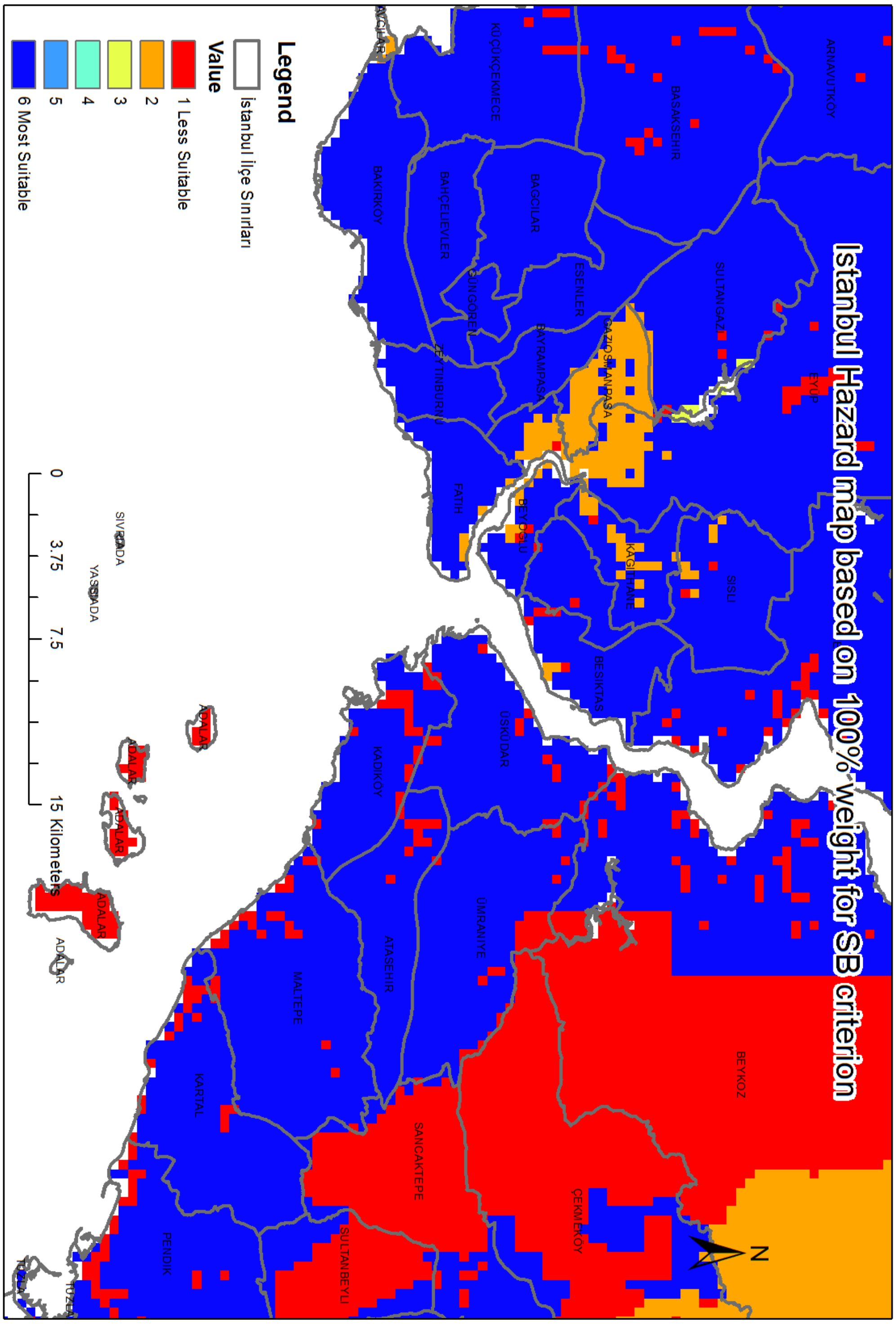

Figure A.109 : Istanbul Hazard map based on 100% weight for SB criterion

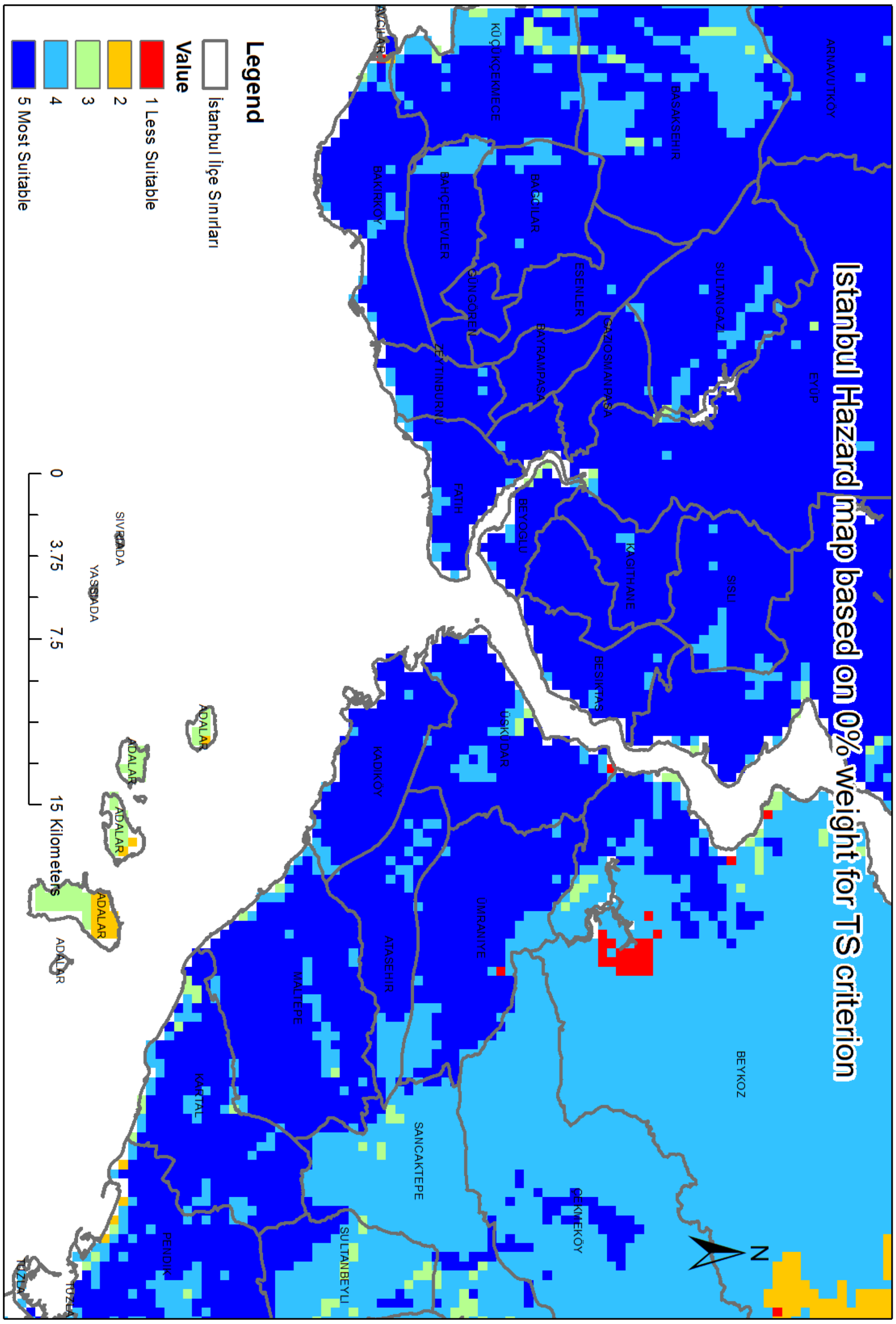

Figure A.110 : Istanbul Hazard map based on 0% weight for TS criterion

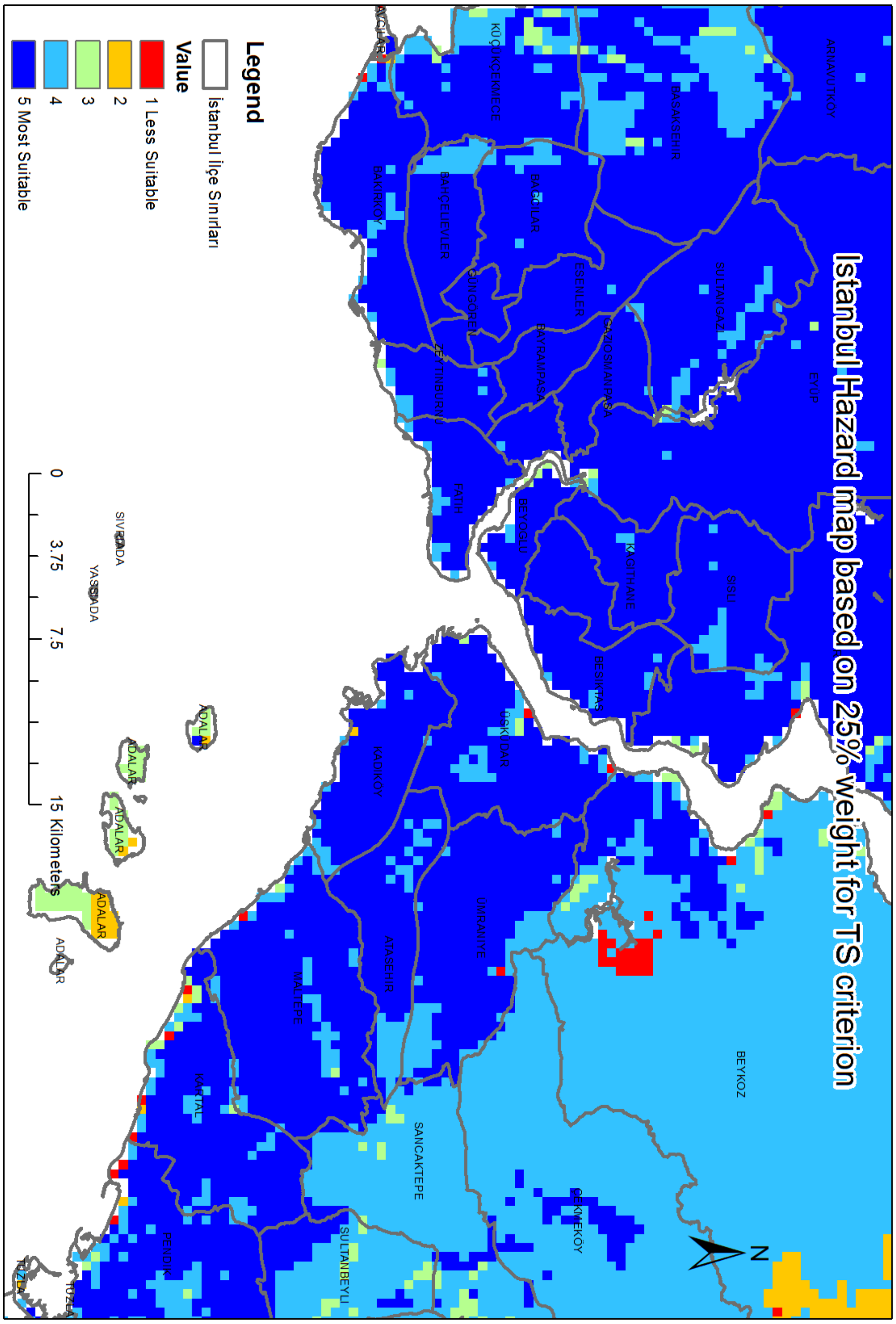

Figure A.111 : Istanbul Hazard map based on 25% weight for TS criterion

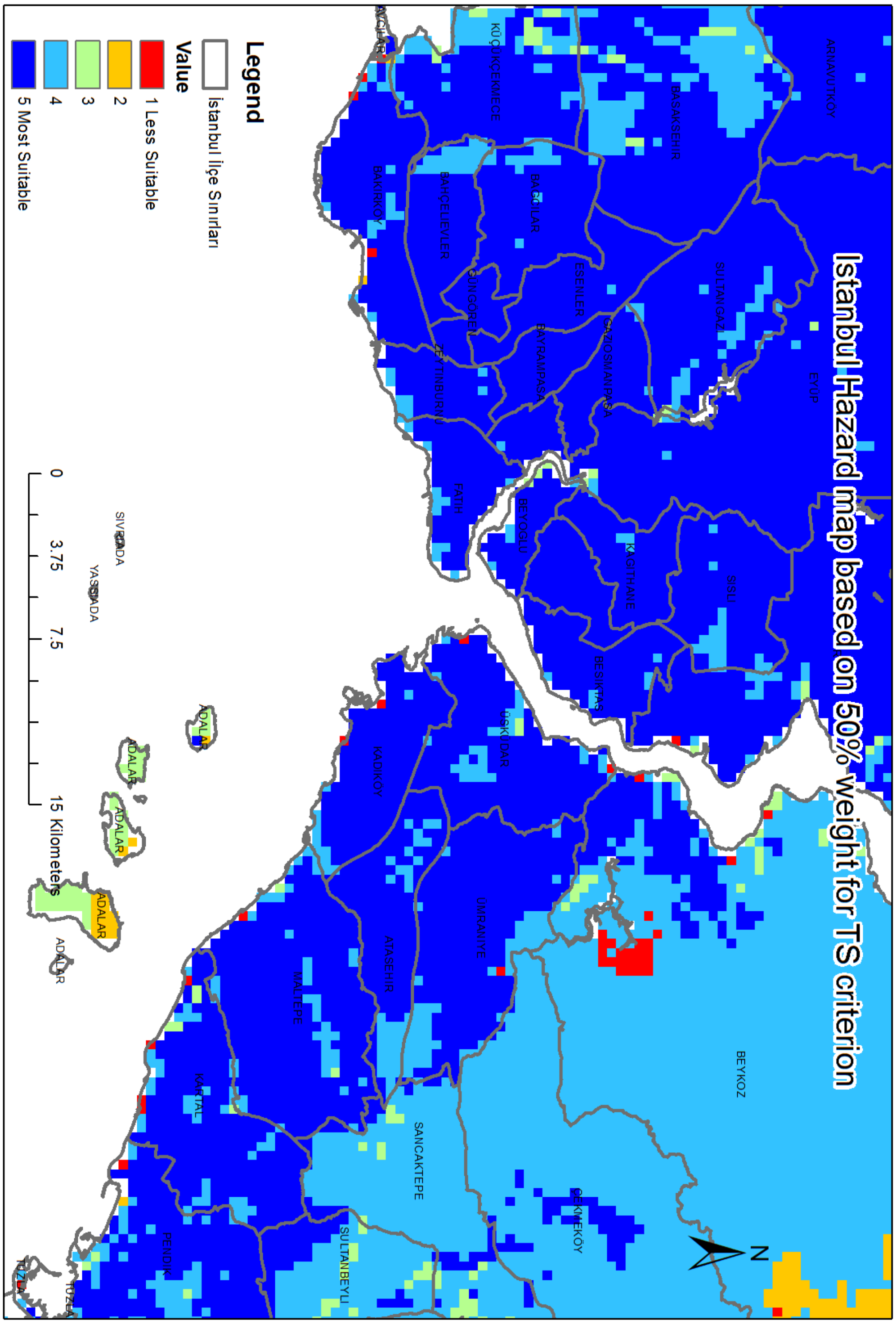

Figure A.112 : Istanbul Hazard map based on 50% weight for TS criterion

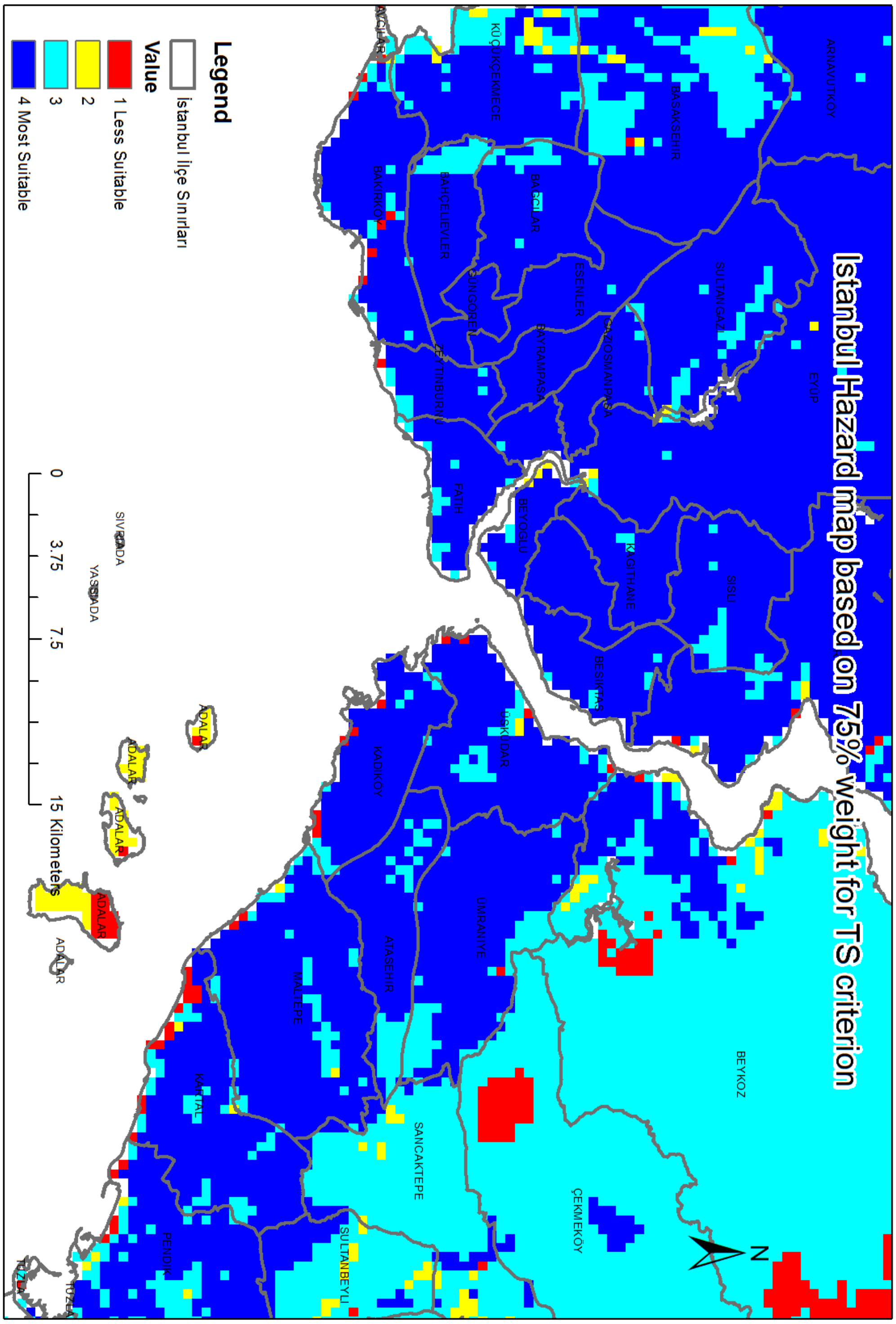

Figure A.113 : Istanbul Hazard map based on 75% weight for TS criterion

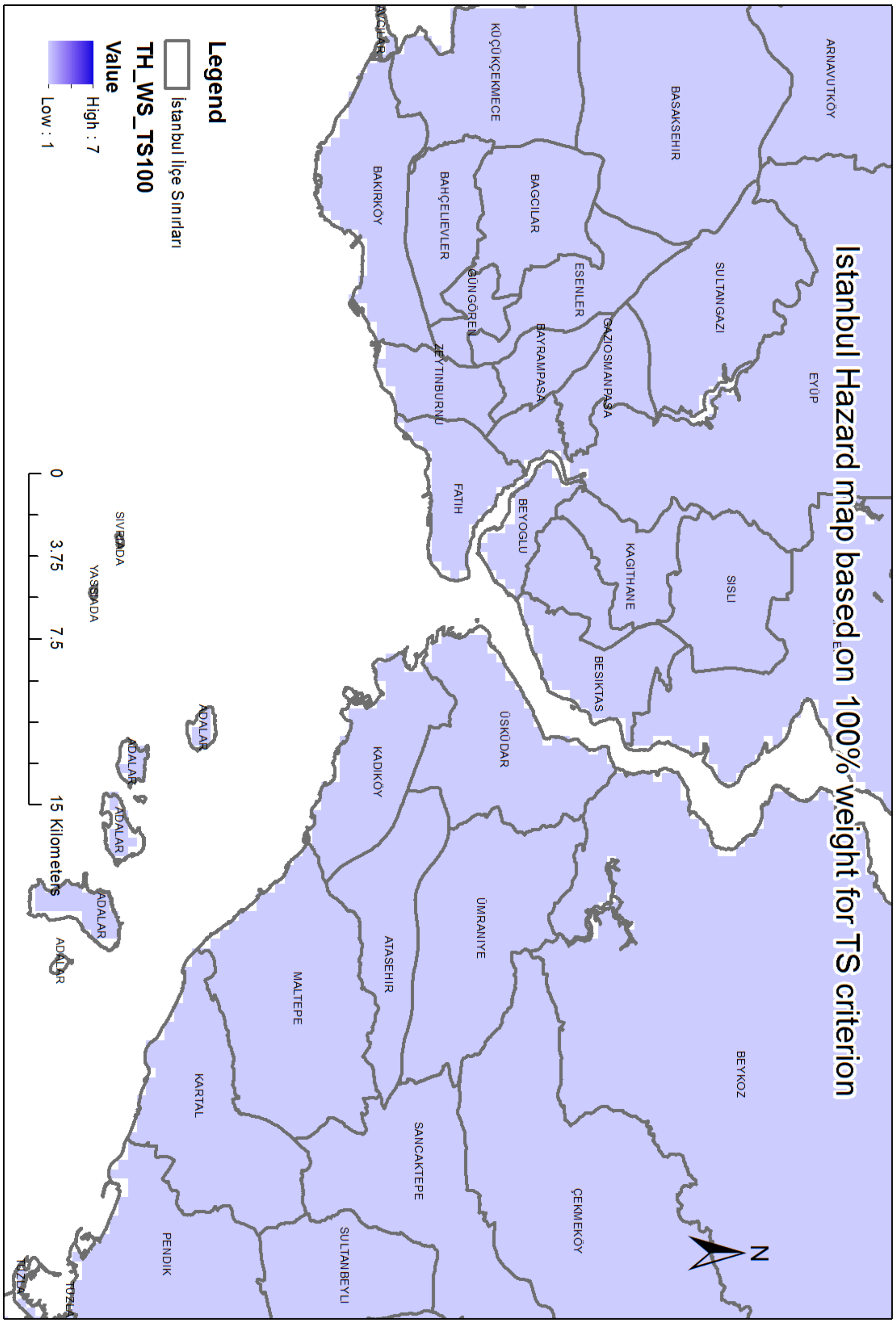

Figure A.114 : Istanbul Hazard map based on 100% weight for TS criterion

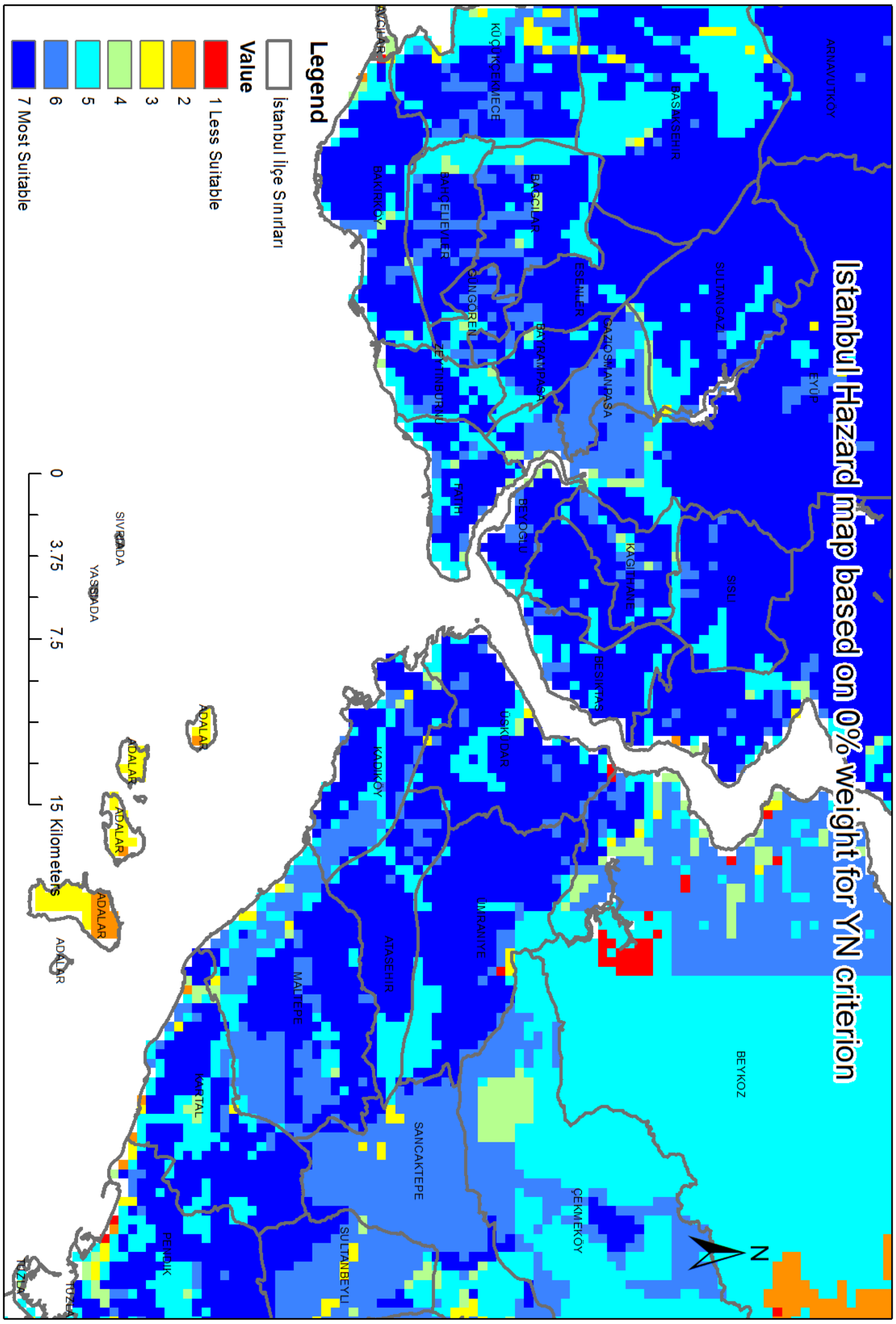

Figure A.115 : Istanbul Hazard map based on 0% weight for YN criterion

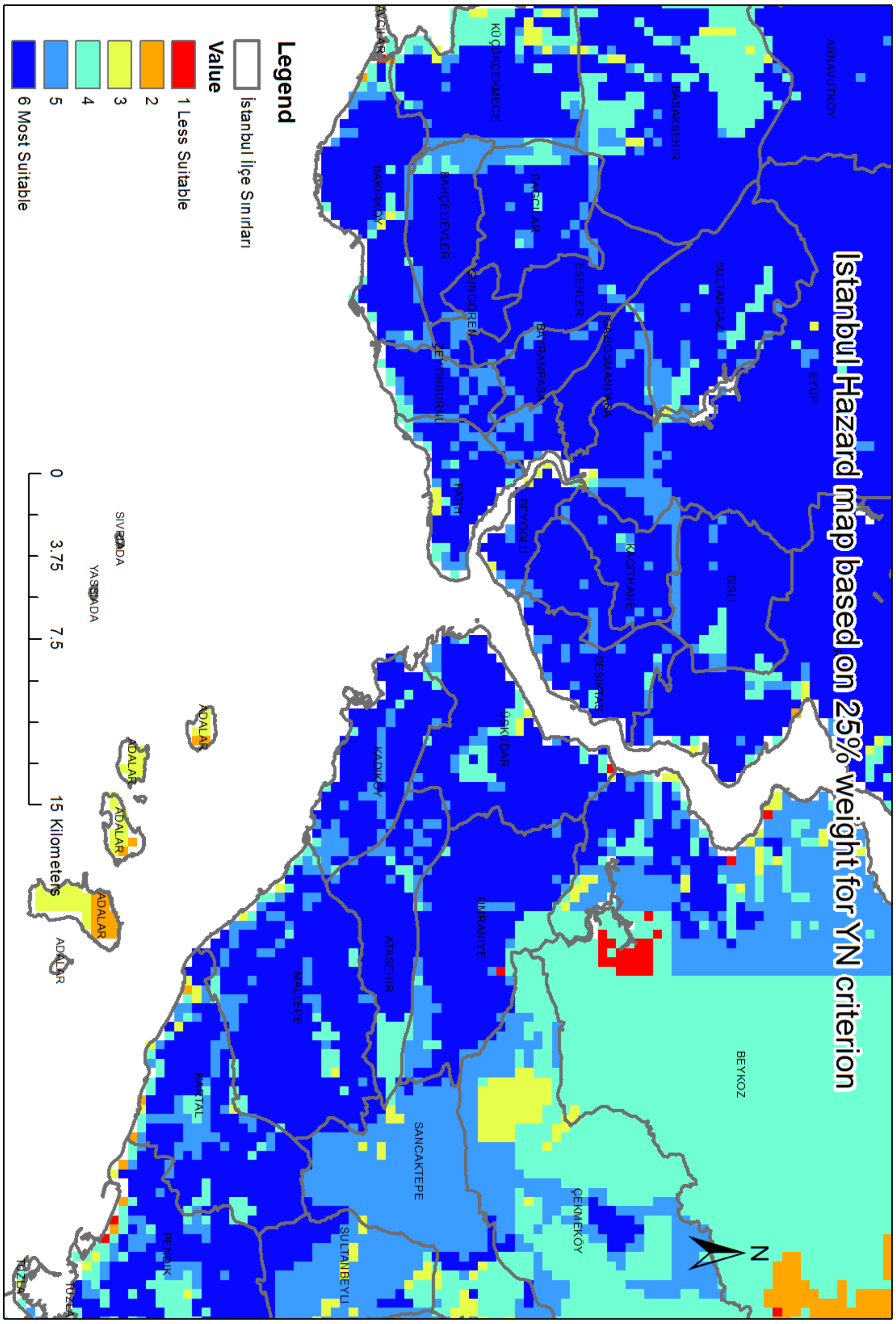

Figure A.116 : Istanbul Hazard map based on 25% weight for YN criterion

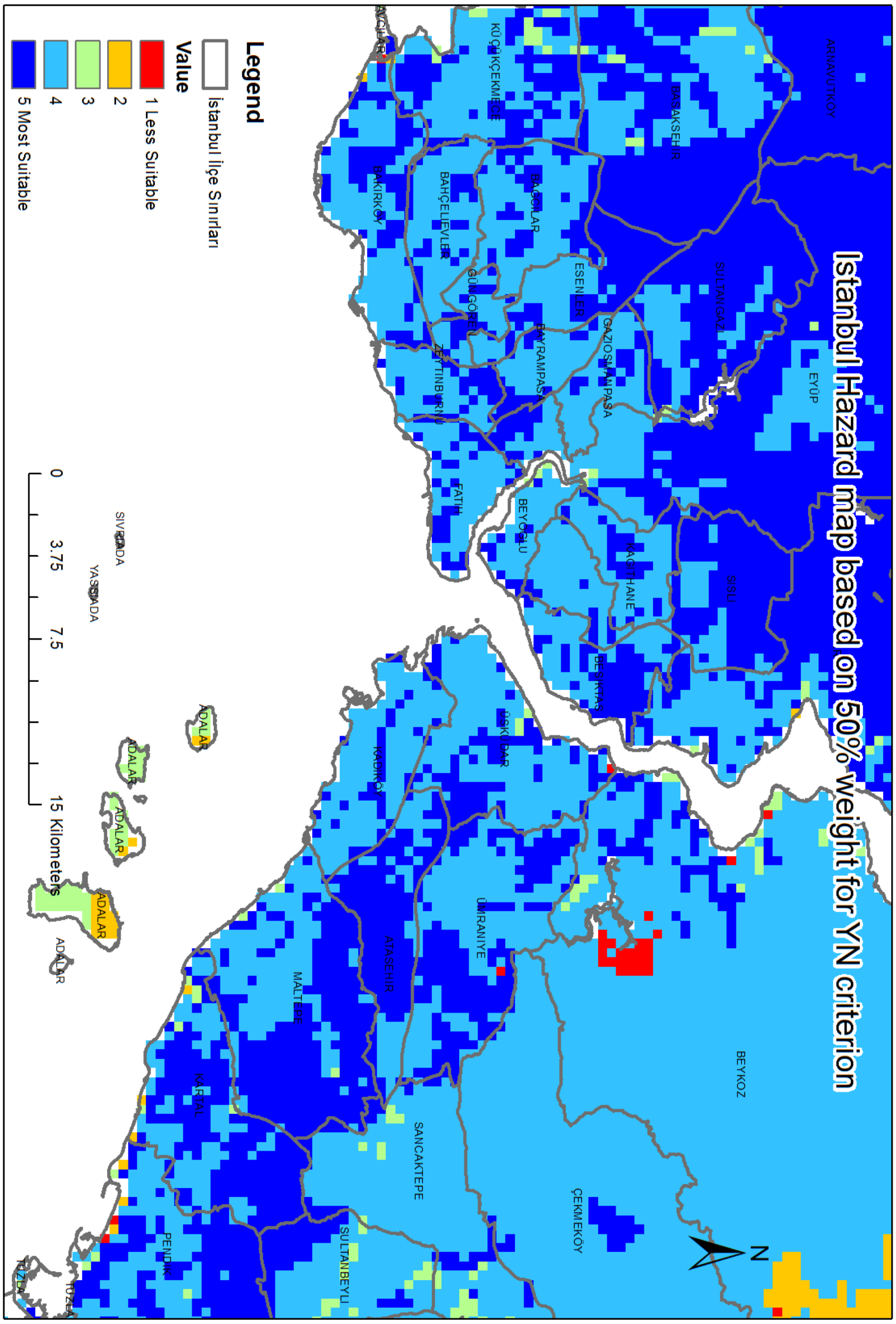

Figure A.117 : Istanbul Hazard map based on 50% weight for YN criterion

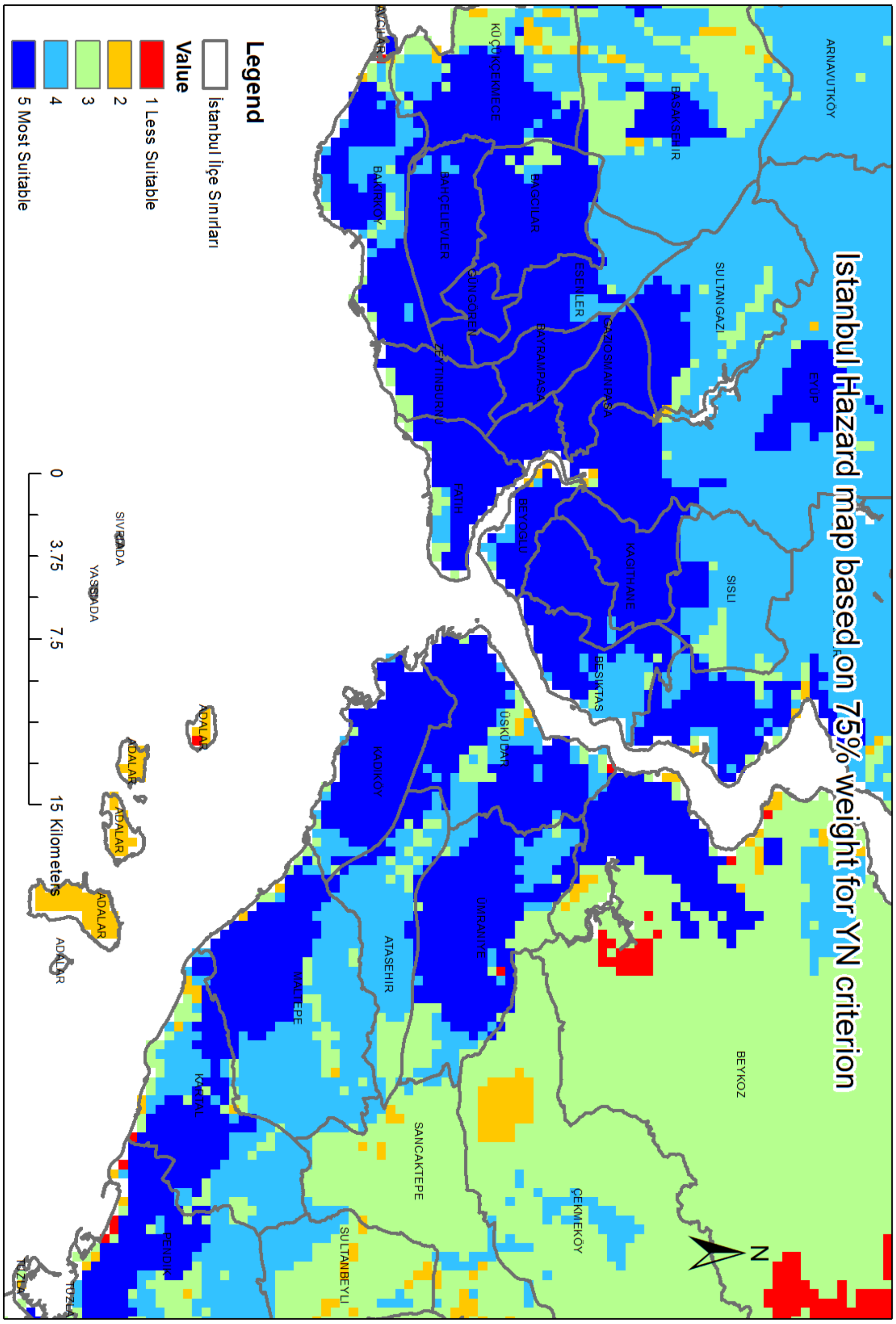

Figure A.118 : Istanbul Hazard map based on 75% weight for YN criterion

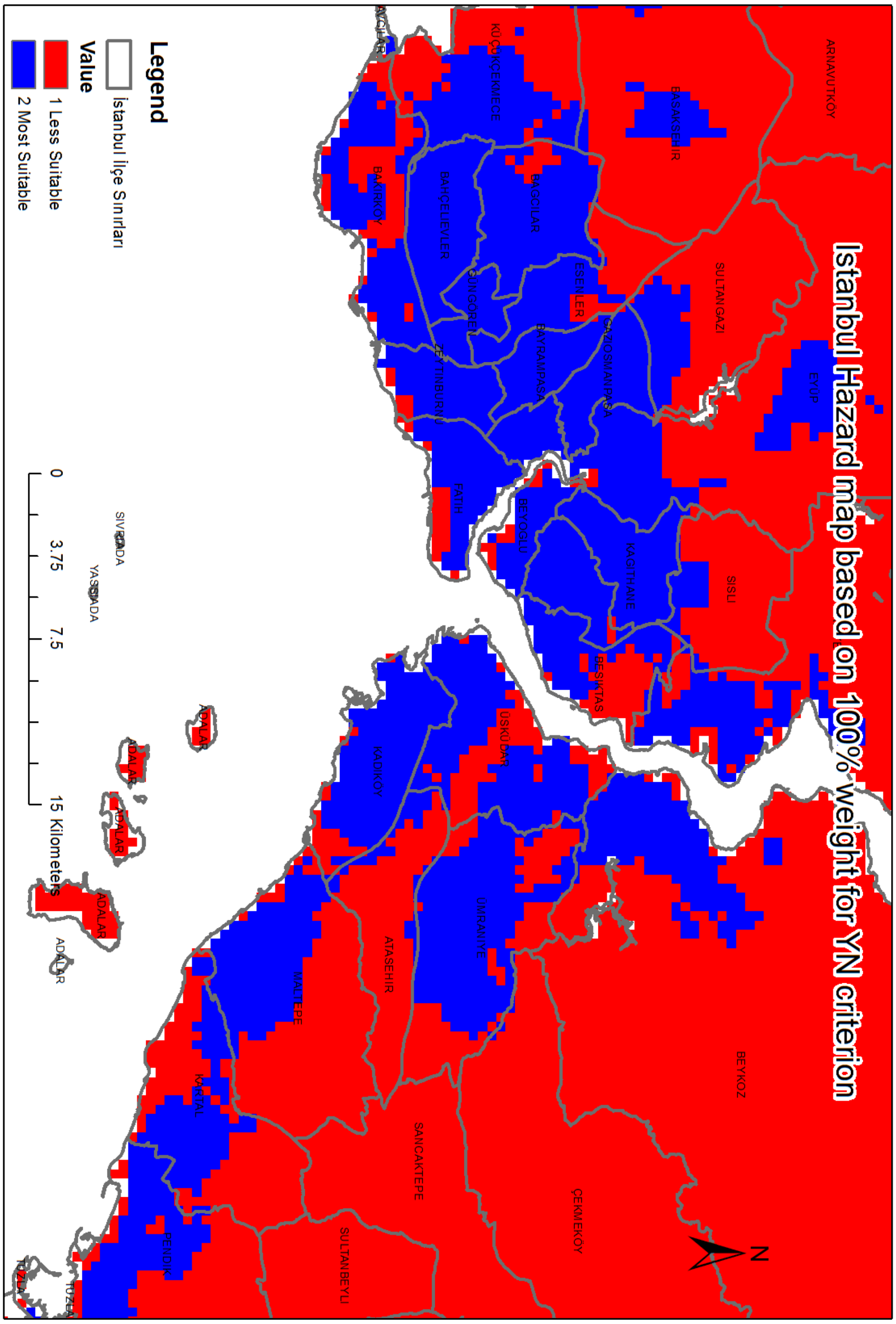

Figure A.119 : Istanbul Hazard map based on 100% weight for YN criterion

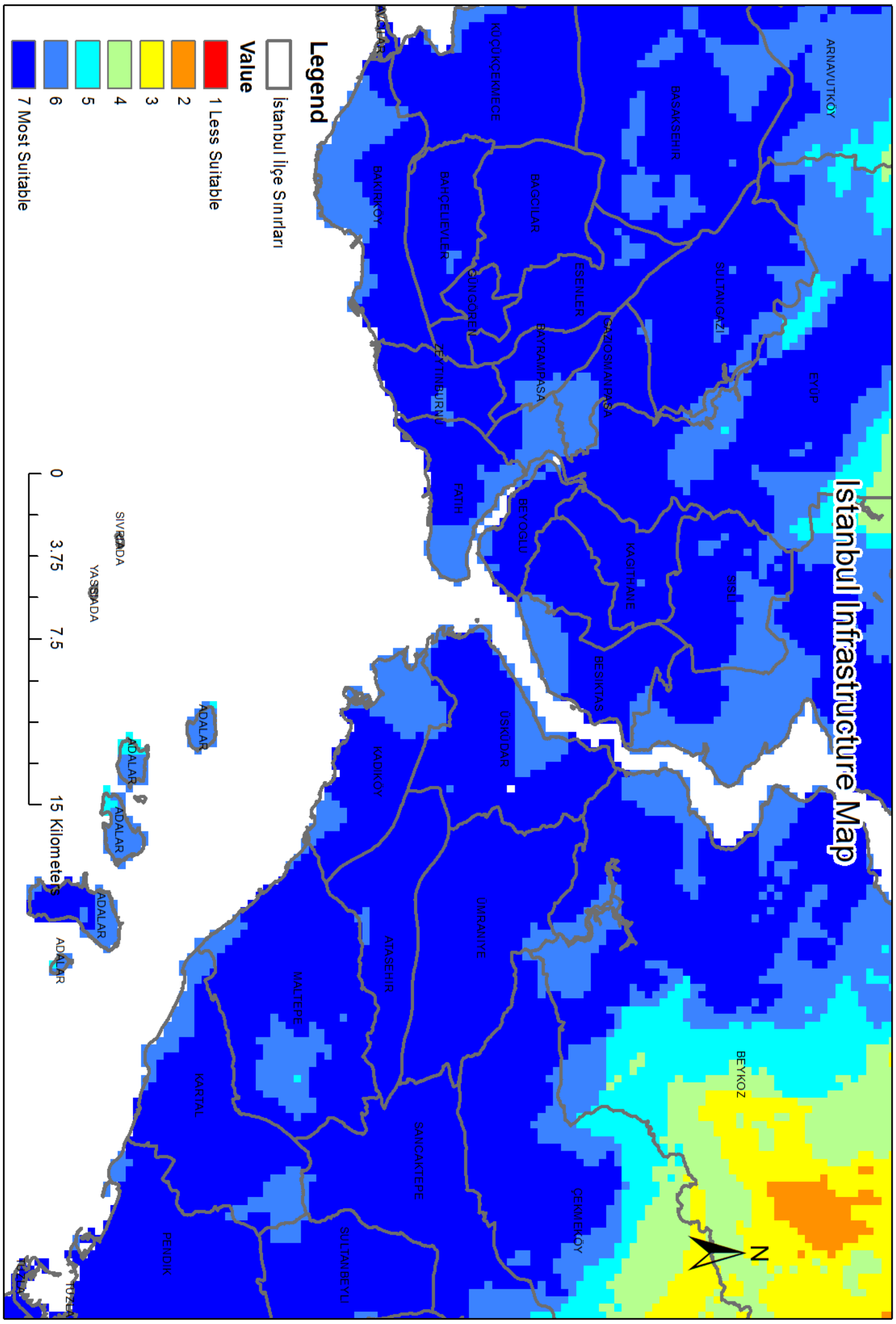

Figure A.120 : Istanbul Infrastructure Map

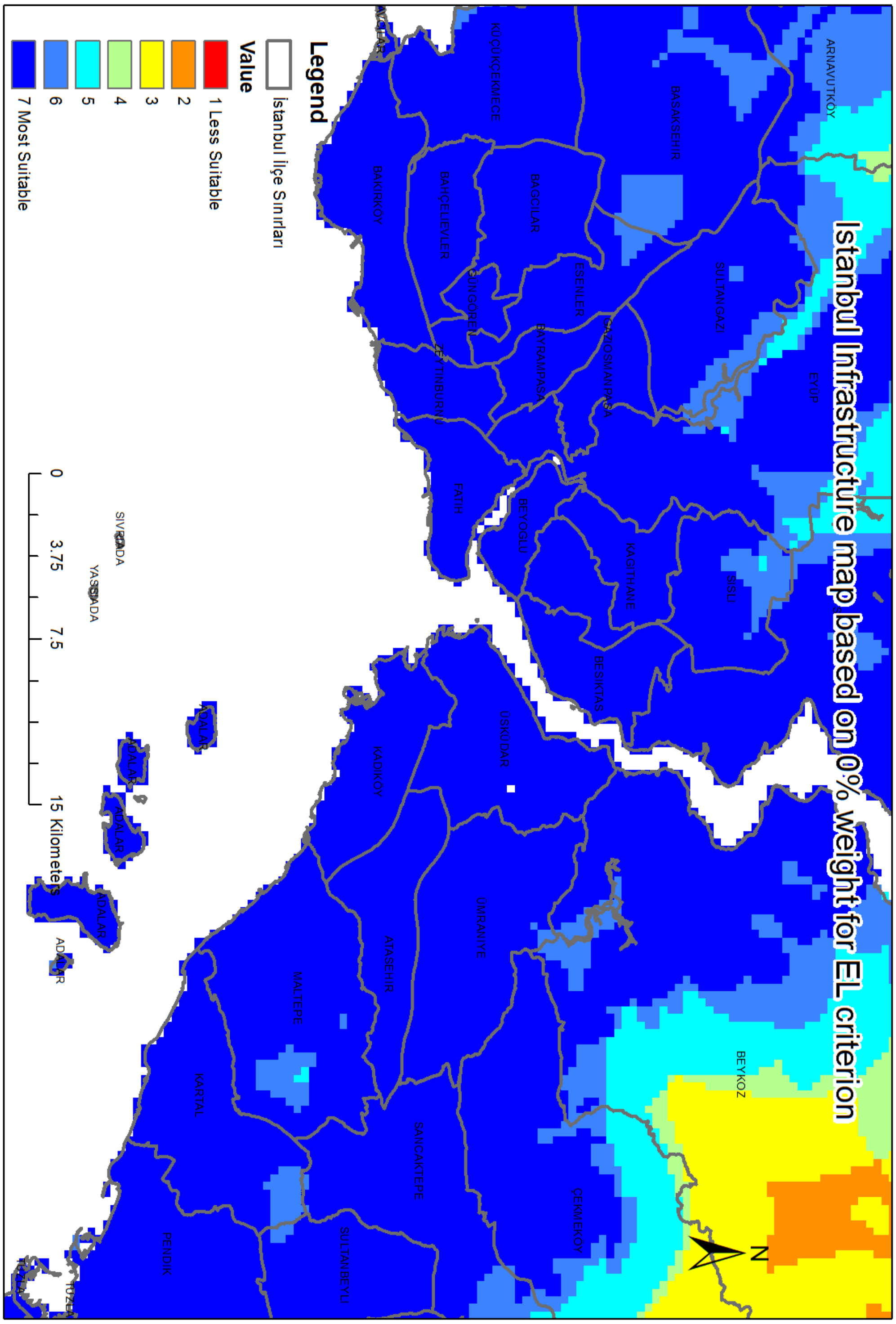

Figure A.121 : Istanbul Infrastructure map based on 0% weight for EL criterion

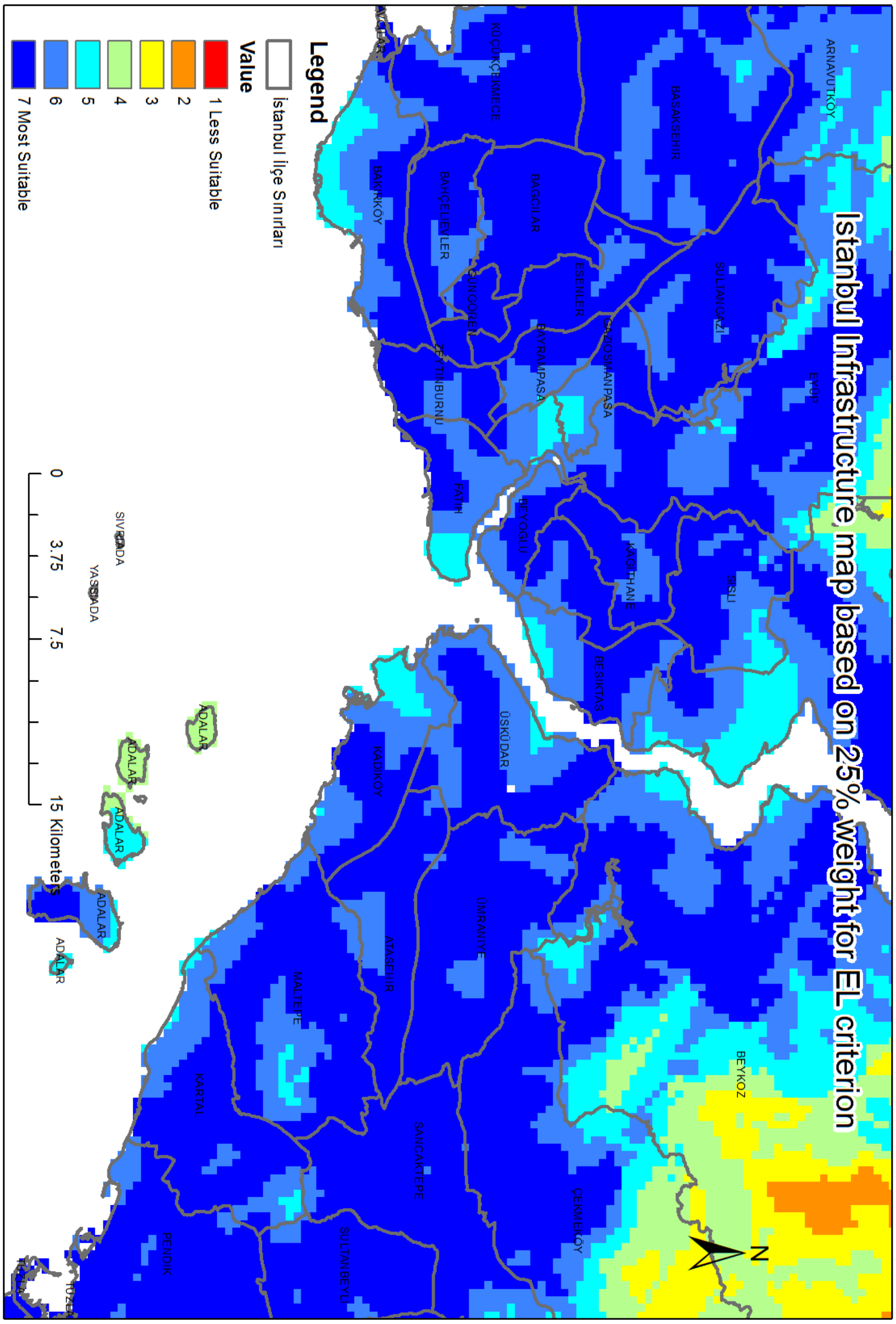

Figure A.122 : Istanbul Infrastructure map based on 25% weight for EL criterion

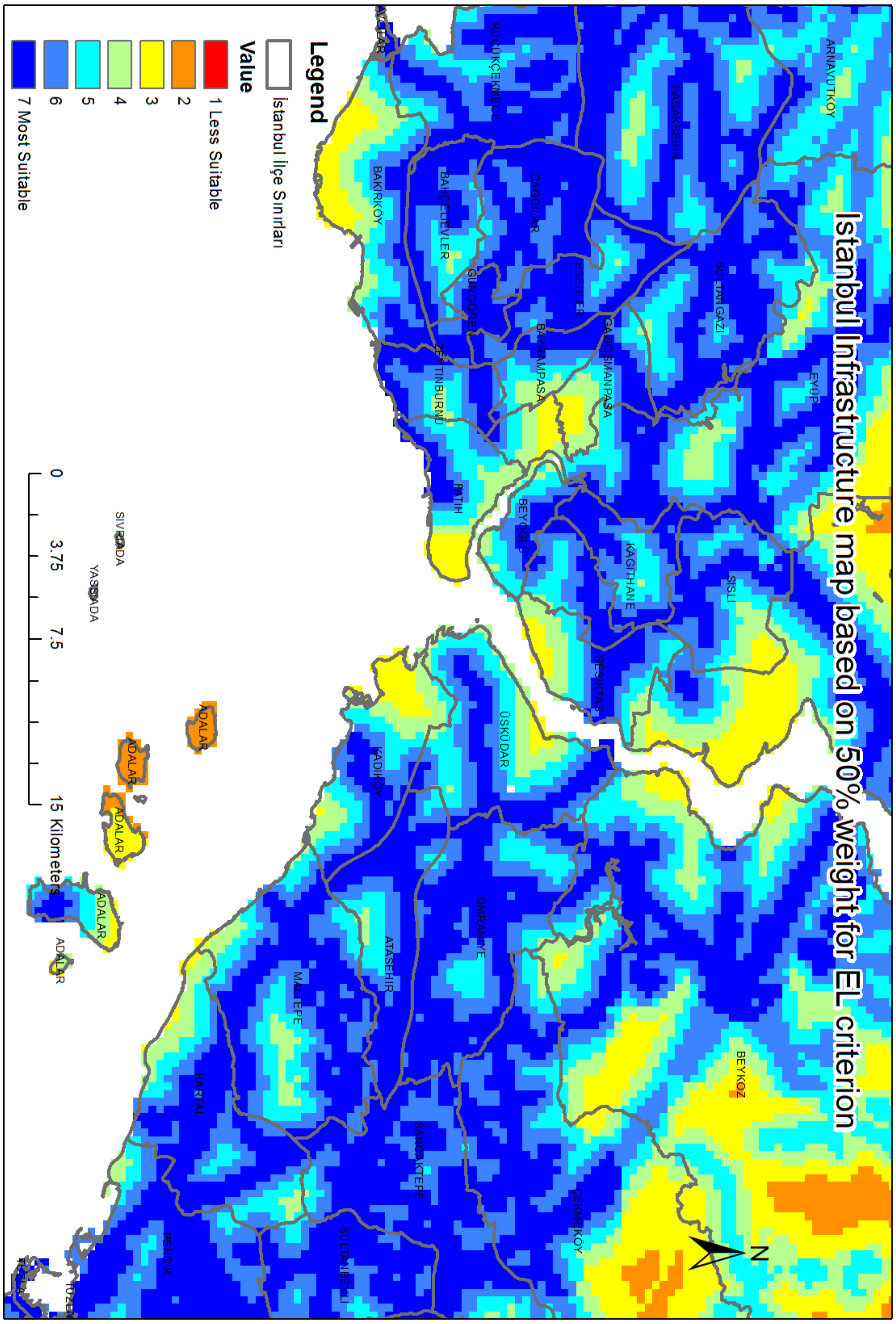

Figure A.123 : Istanbul Infrastructure map based on 50% weight for EL criterion

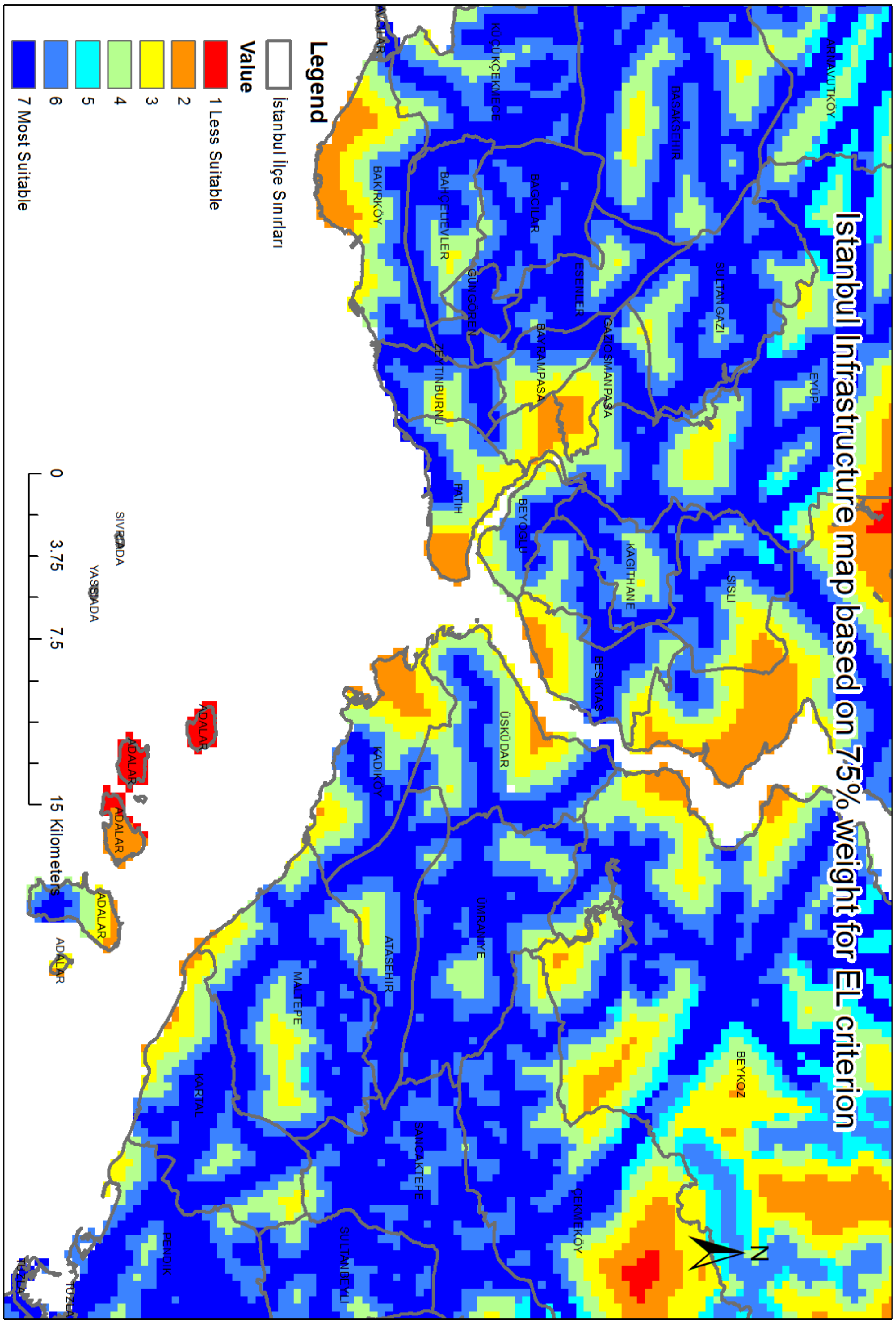

Figure A.124 : Istanbul Infrastructure map based on 75% weight for EL criterion

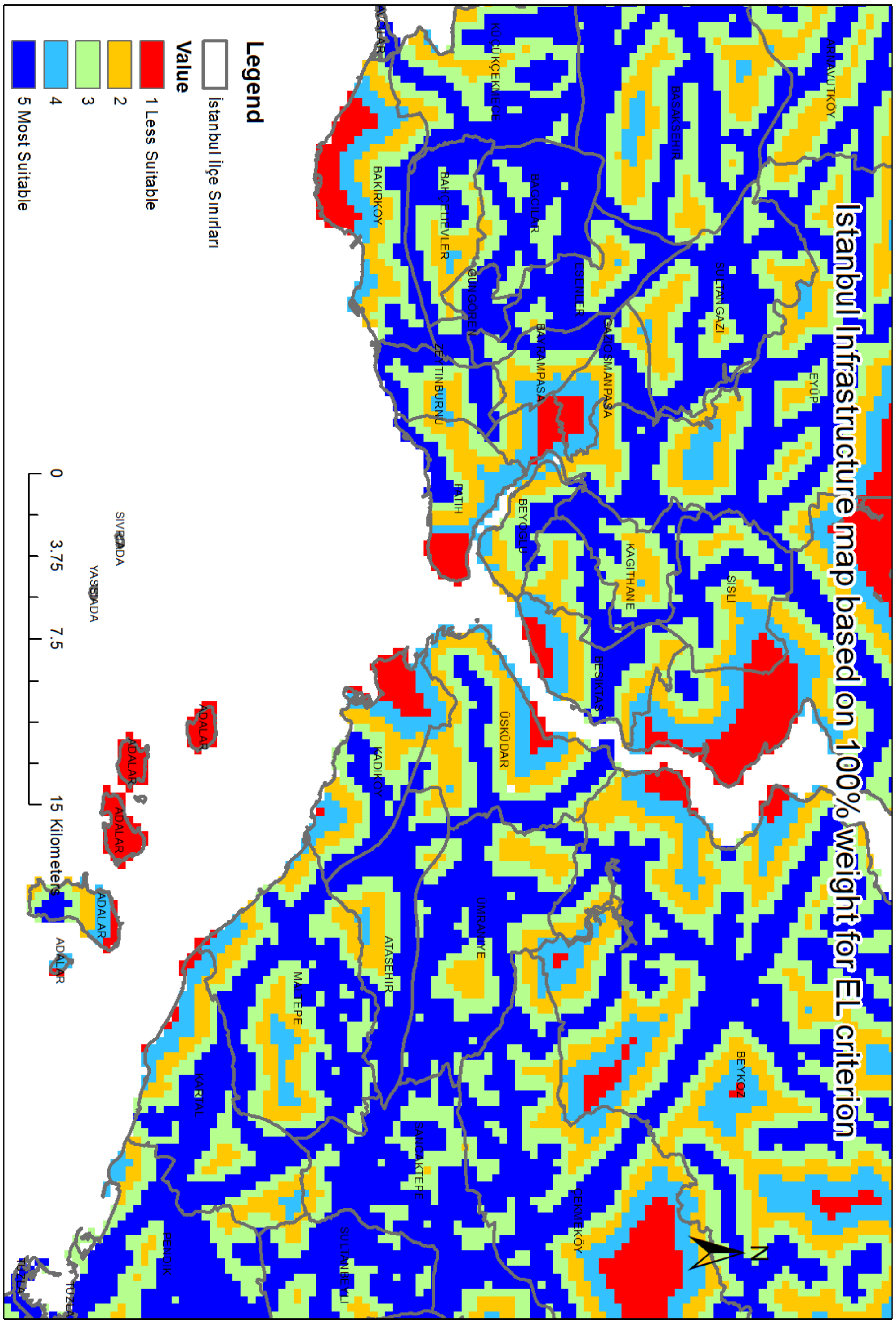

Figure A.125 : Istanbul Infrastructure map based on 100% weight for EL criterion

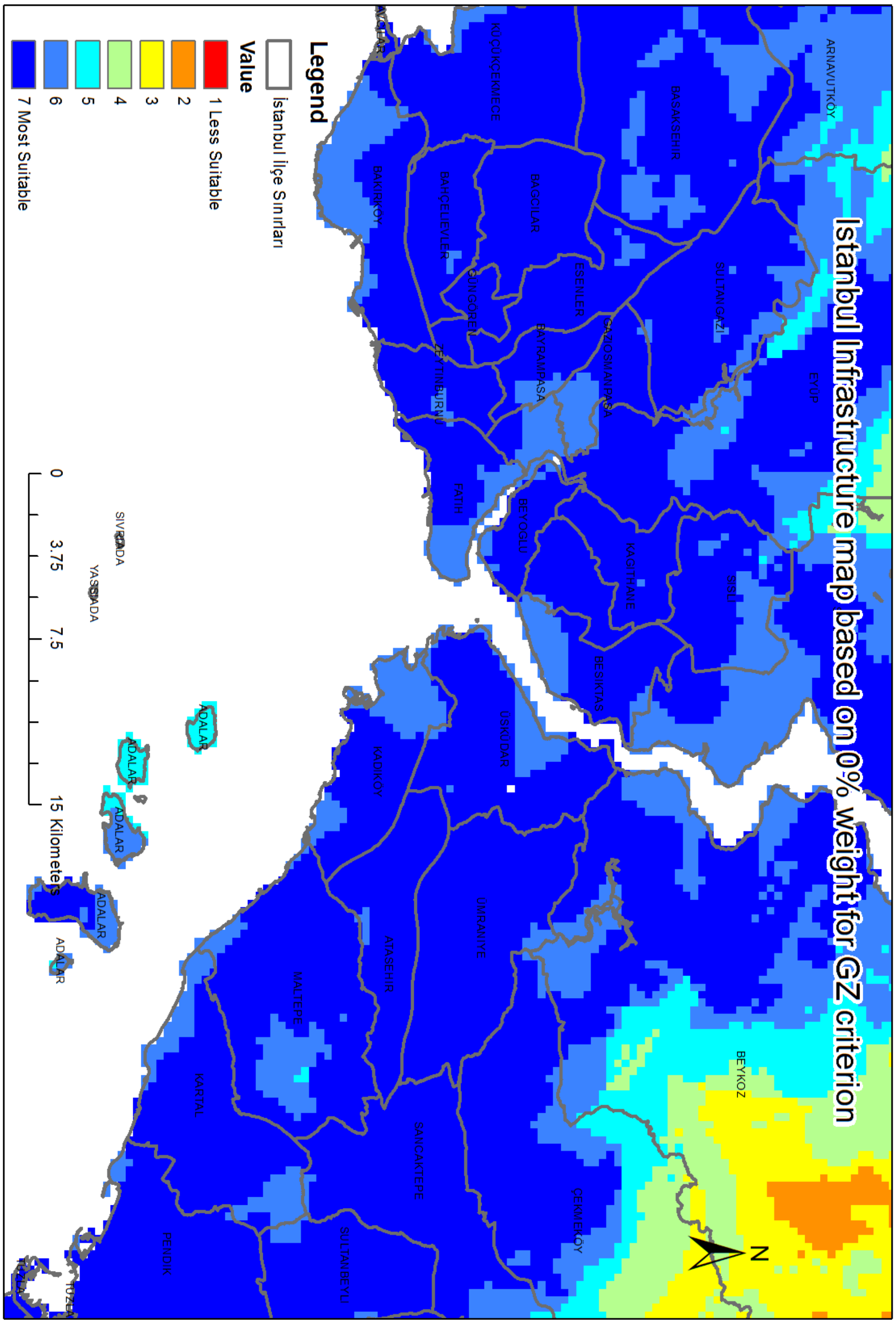

Figure A.126 : Istanbul Infrastructure map based on 0% weight for GZ criterion

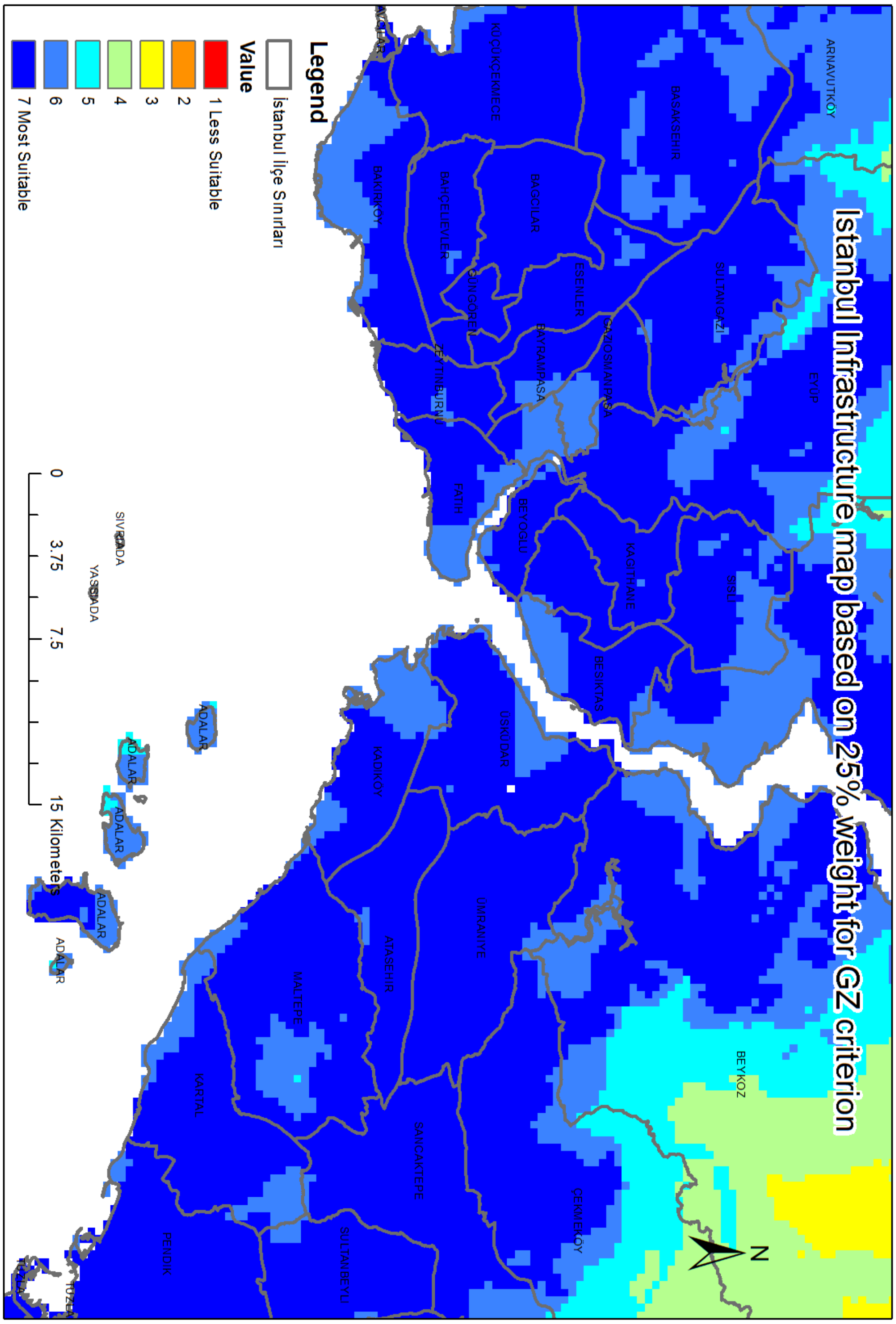

Figure A.127 : Istanbul Infrastructure map based on 25% weight for GZ criterion

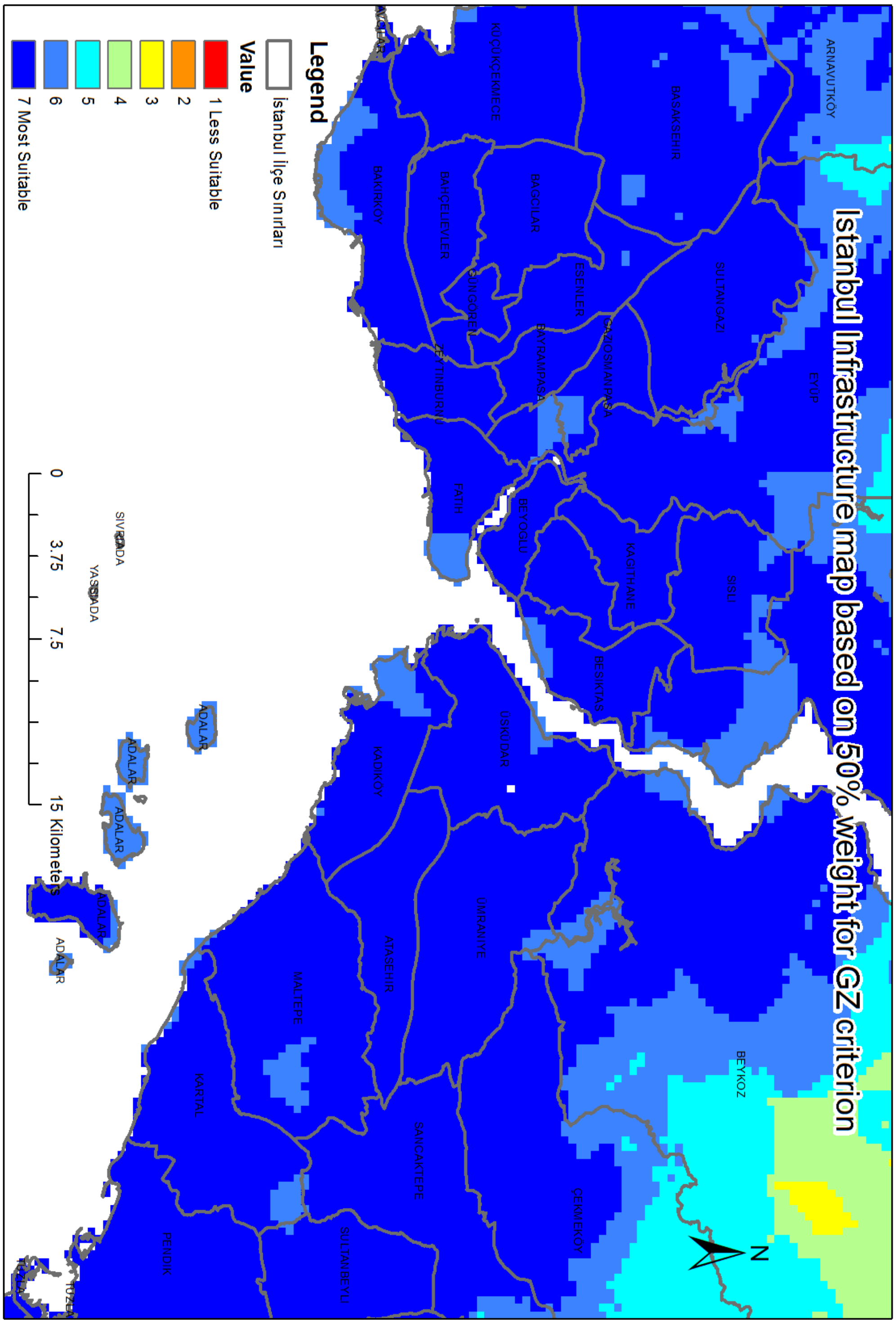

Figure A.128 : Istanbul Infrastructure map based on 50% weight for GZ criterion

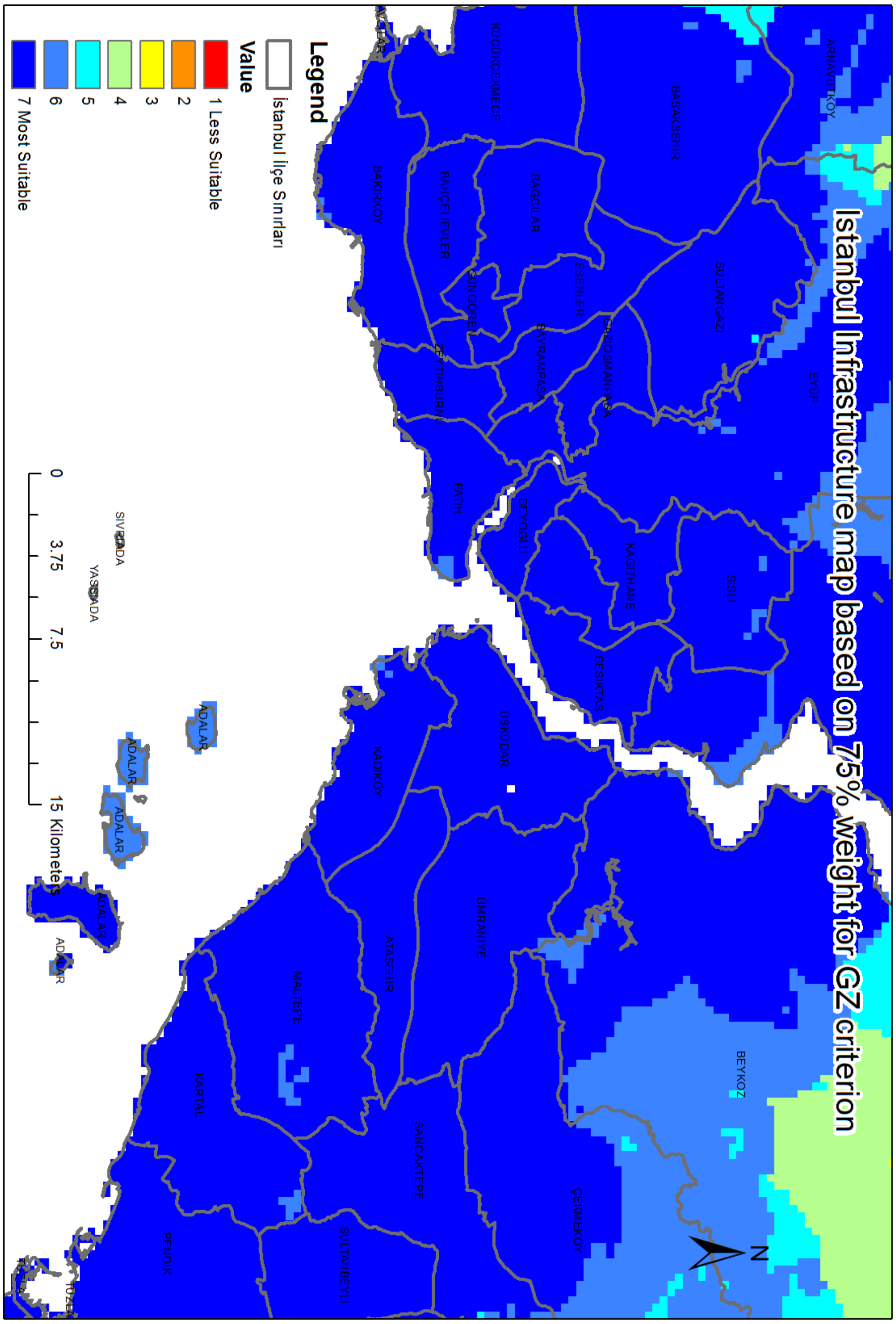

Figure A.129 : Istanbul Infrastructure map based on 75% weight for GZ criterion

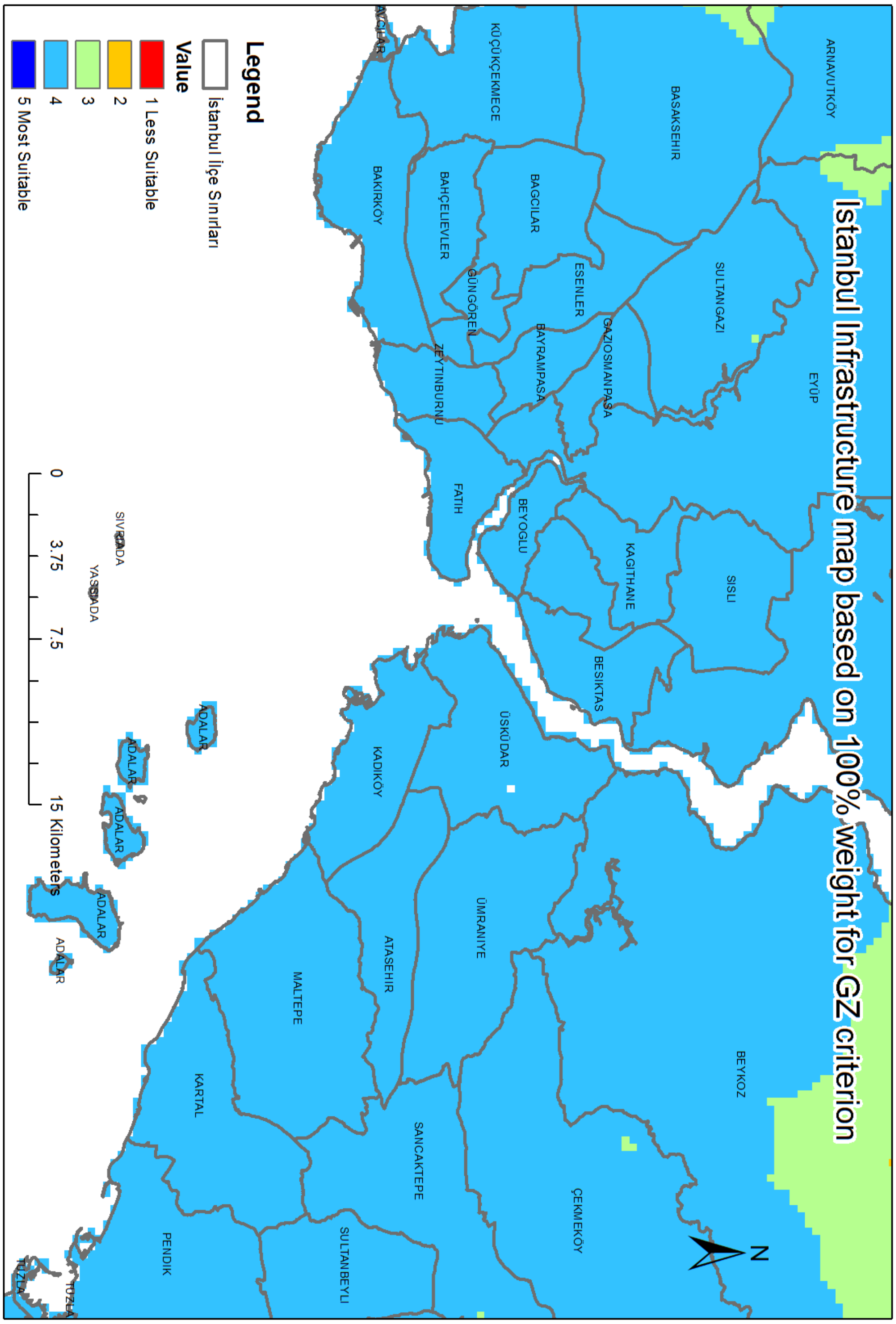

Figure A.130 : Istanbul Infrastructure map based on 100% weight for GZ criterion

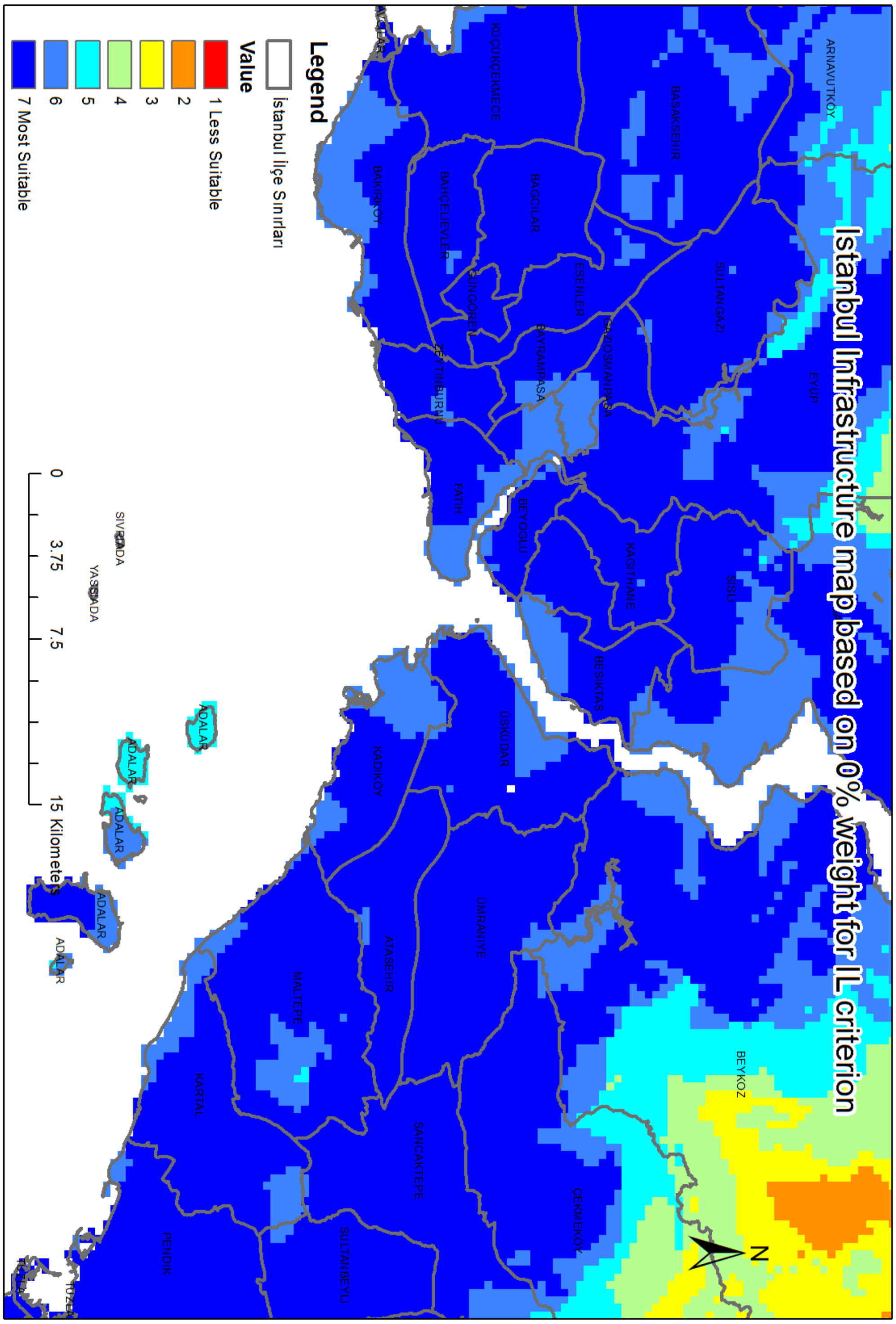

Figure A.131 : Istanbul Infrastructure map based on 0% weight for IL criterion

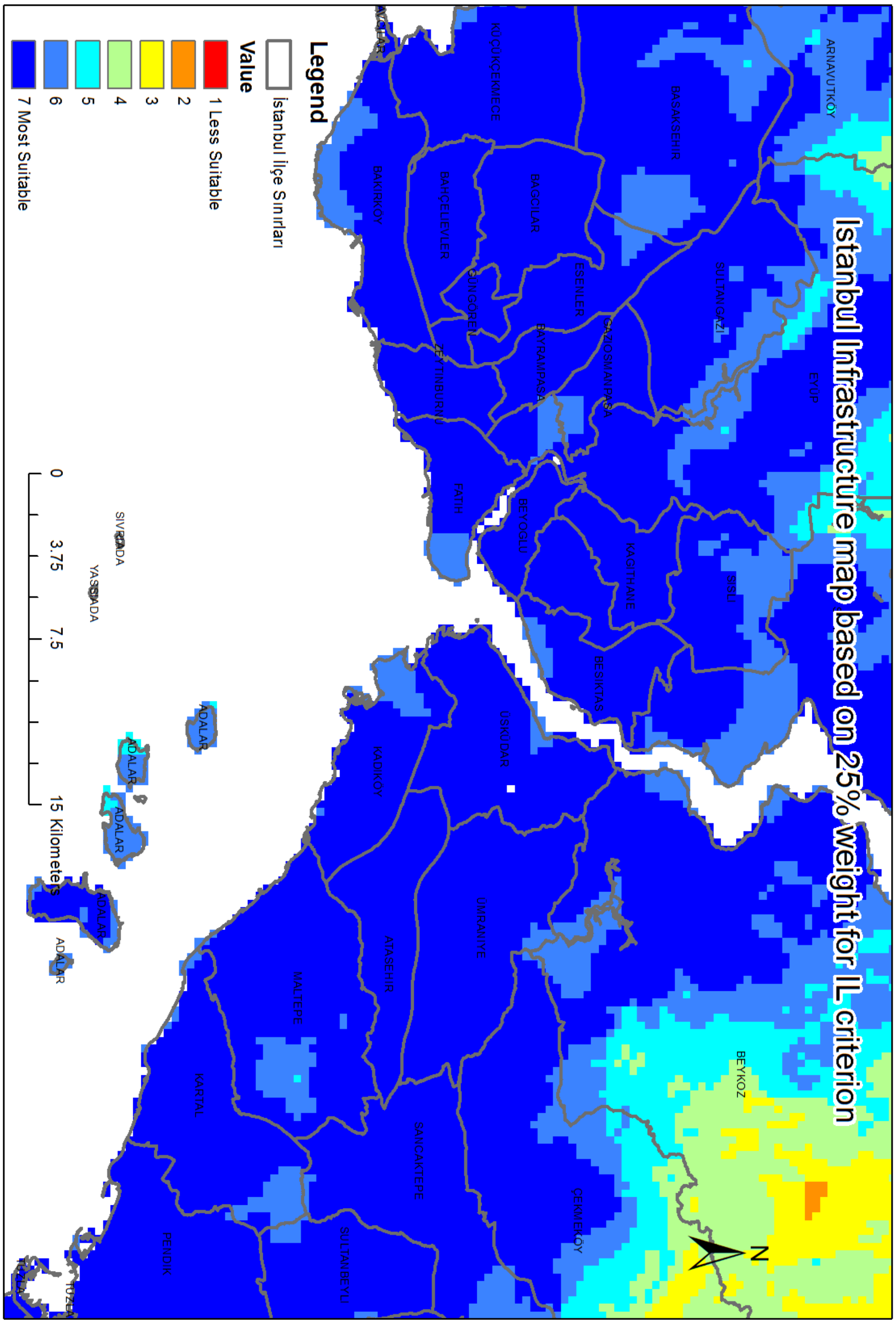

Figure A.132 : Istanbul Infrastructure map based on 25% weight for IL criterion

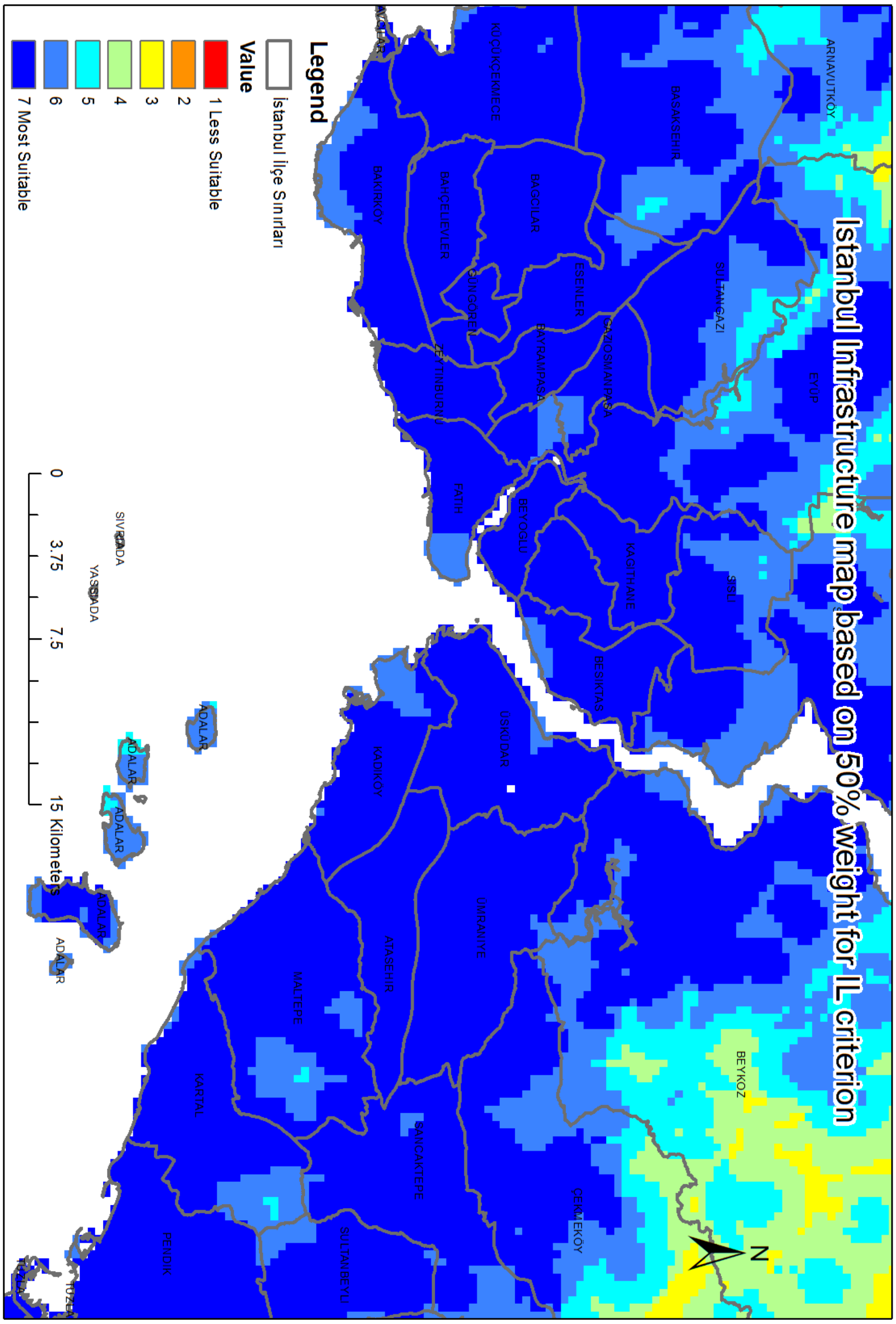

Figure A.133 : Istanbul Infrastructure map based on 50% weight for IL criterion

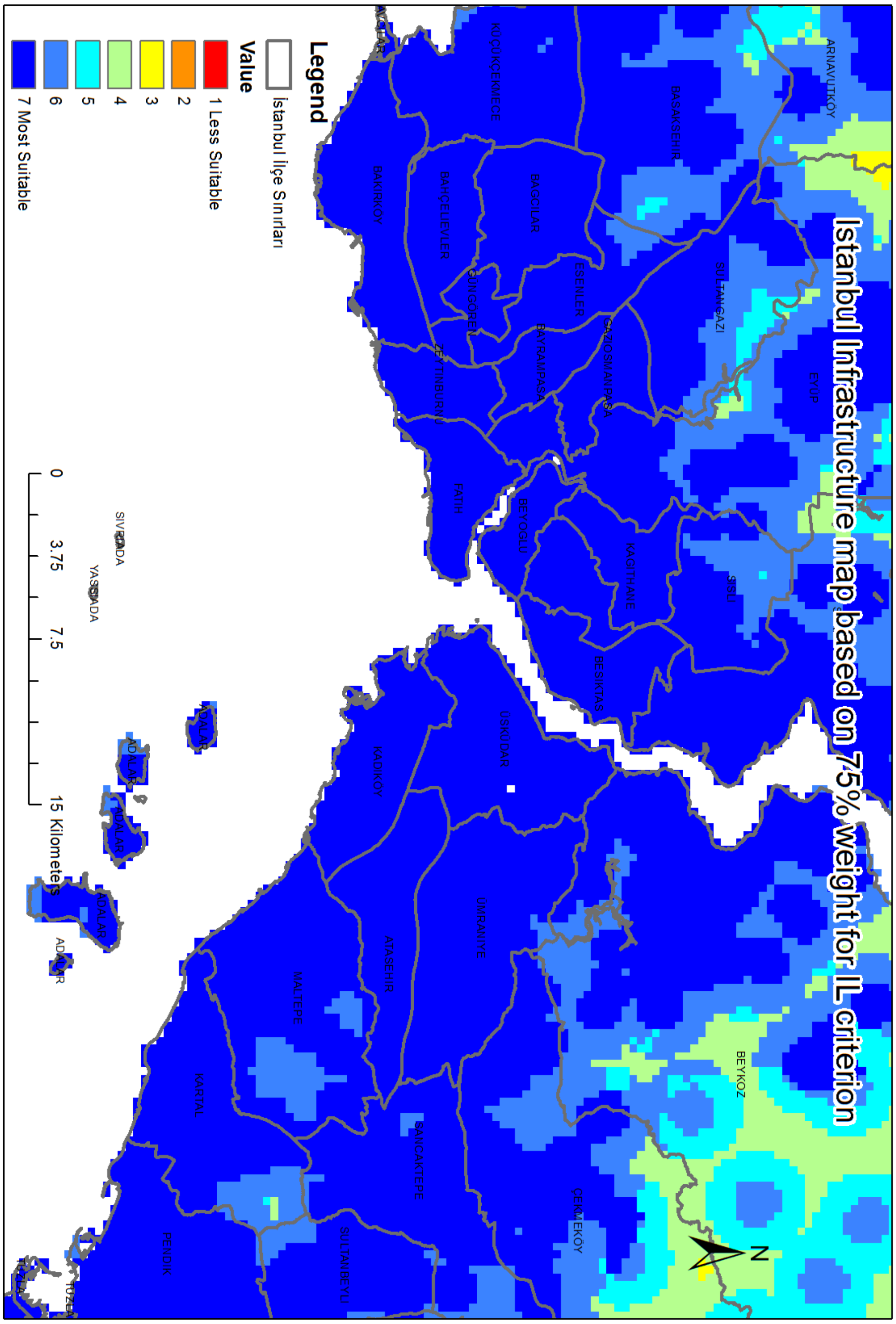

Figure A.134 : Istanbul Infrastructure map based on 75% weight for IL criterion

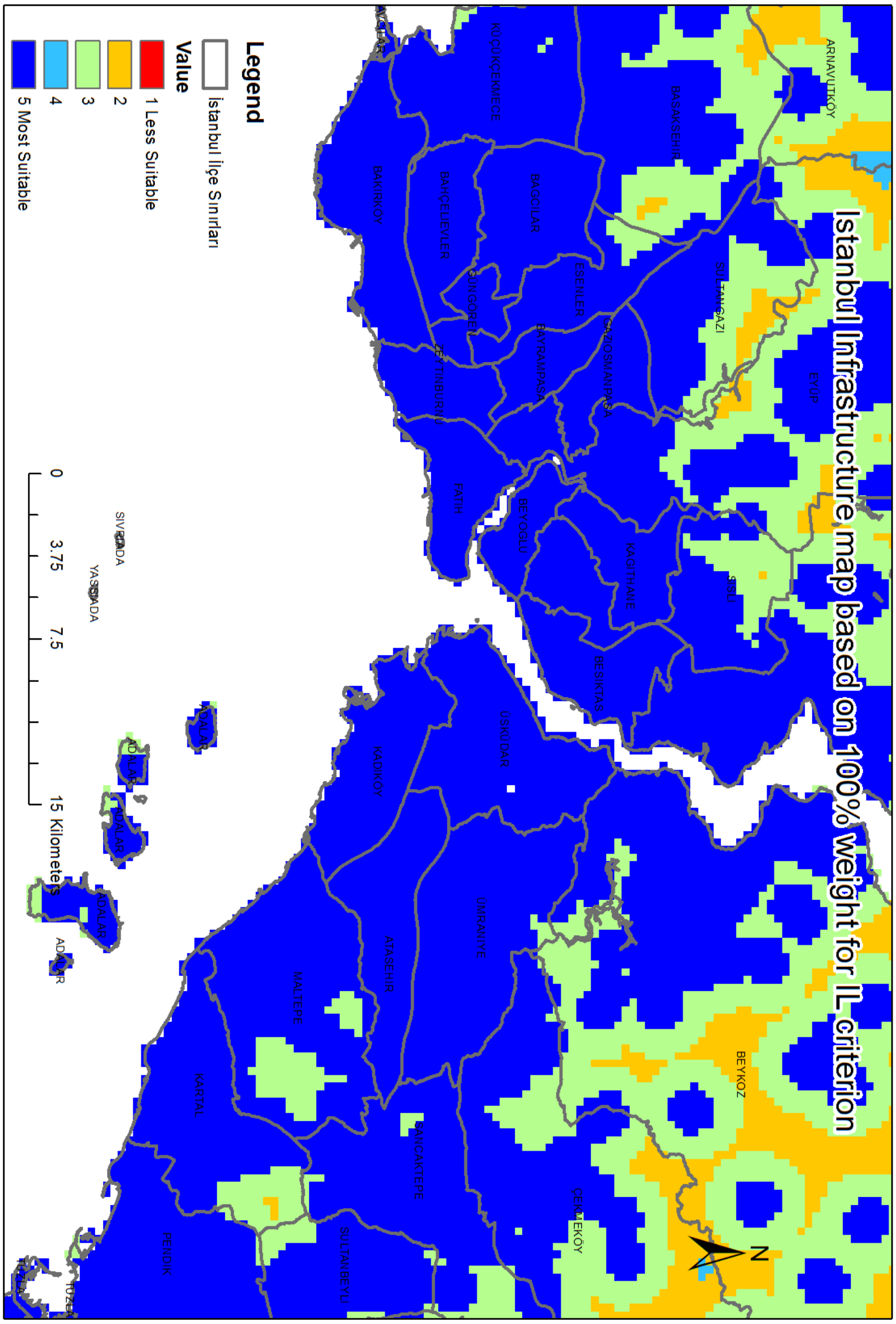

Figure A.135 : Istanbul Infrastructure map based on 100% weight for IL criterion

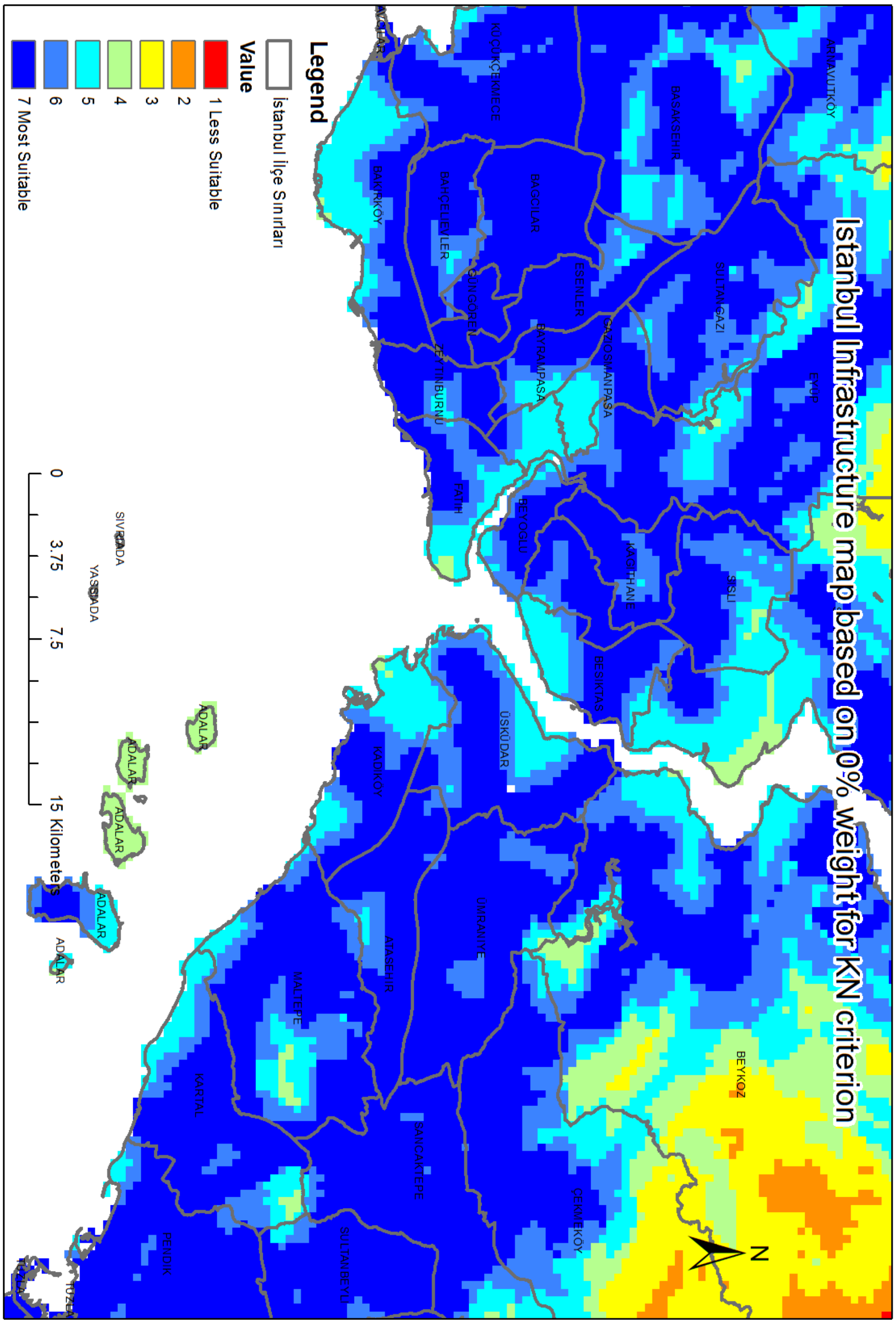

Figure A.136 : Istanbul Infrastructure map based on 0% weight for KN criterion

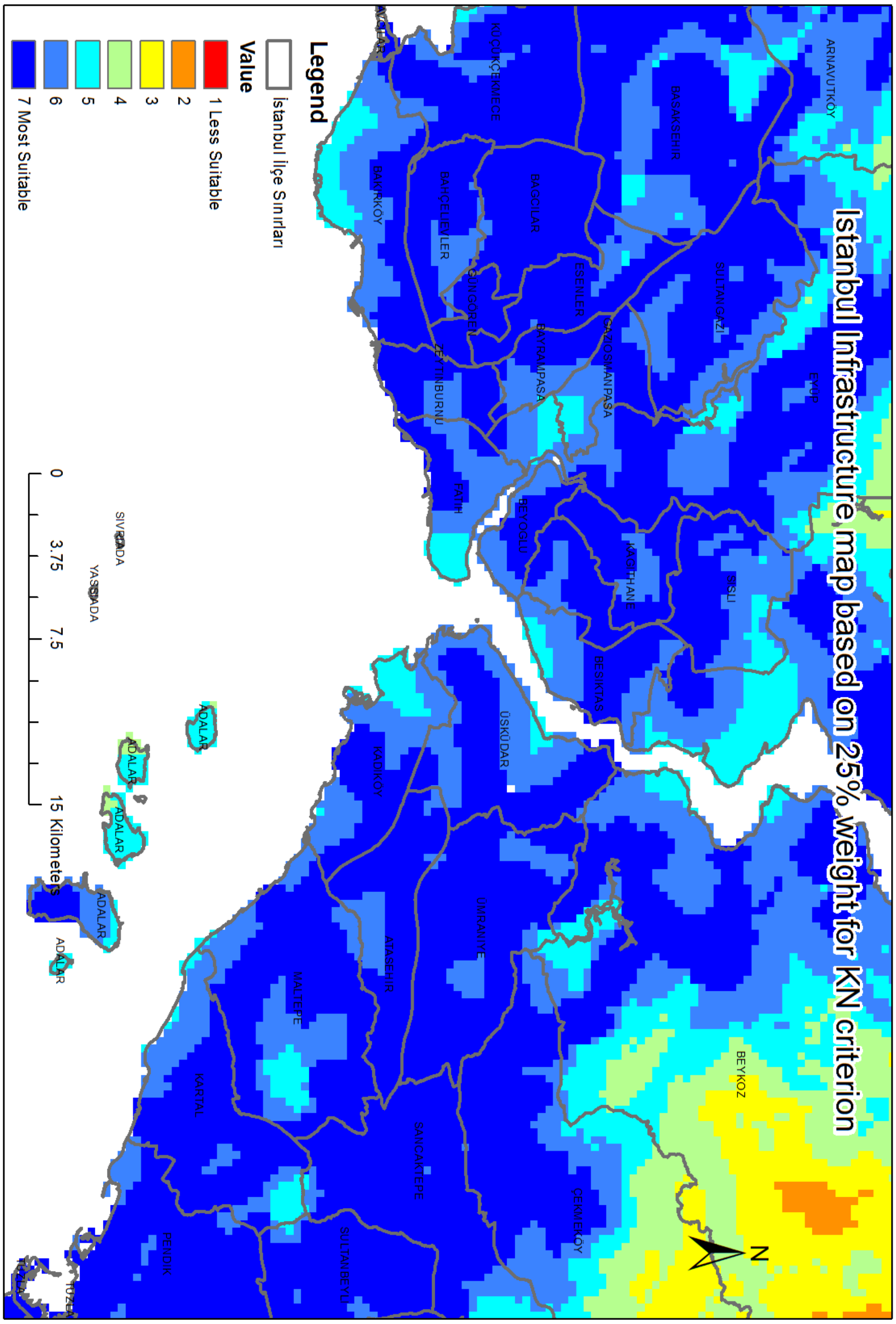

Figure A.137 : Istanbul Infrastructure map based on 25% weight for KN criterion

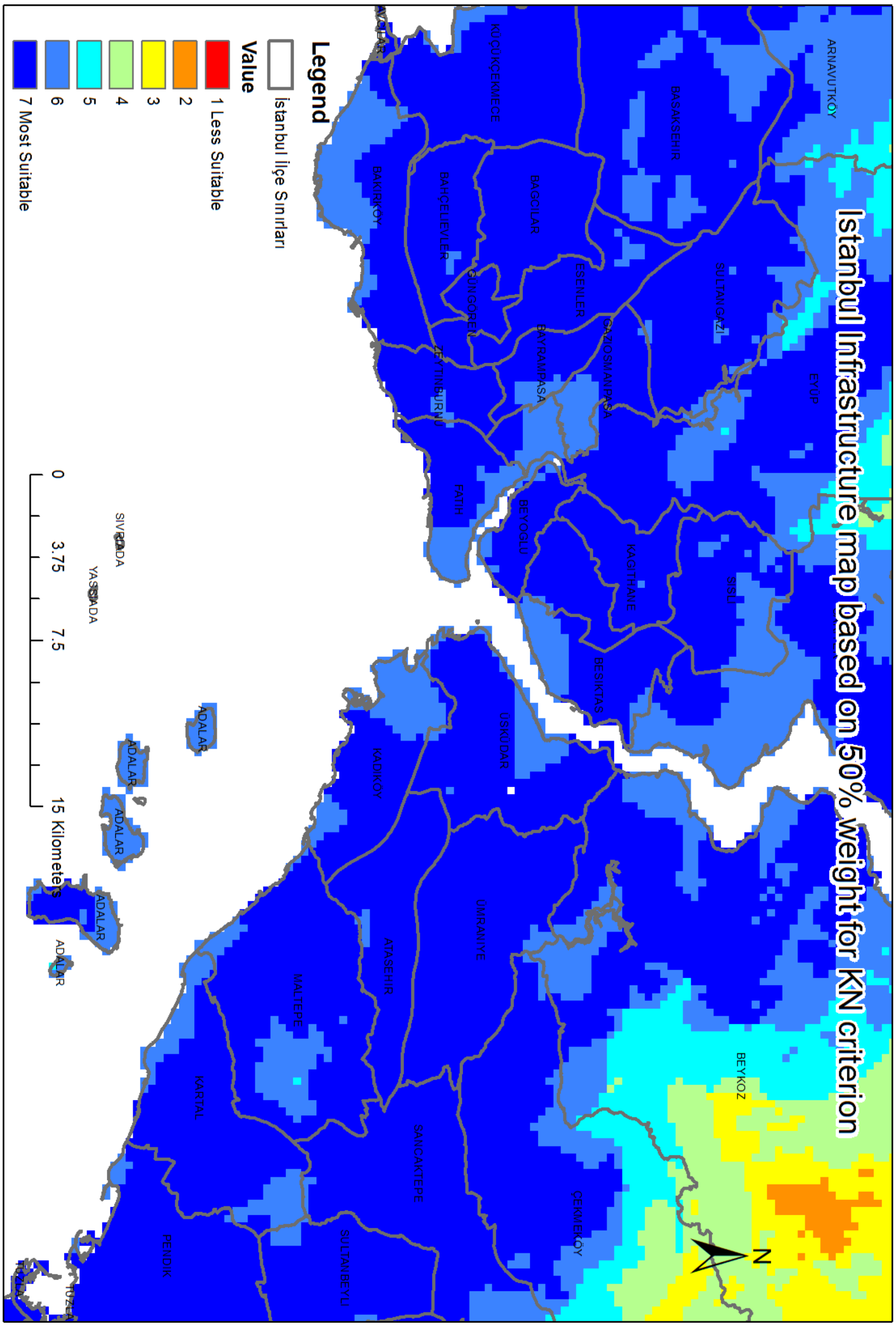

Figure A.138 : Istanbul Infrastructure map based on 50% weight for KN criterion

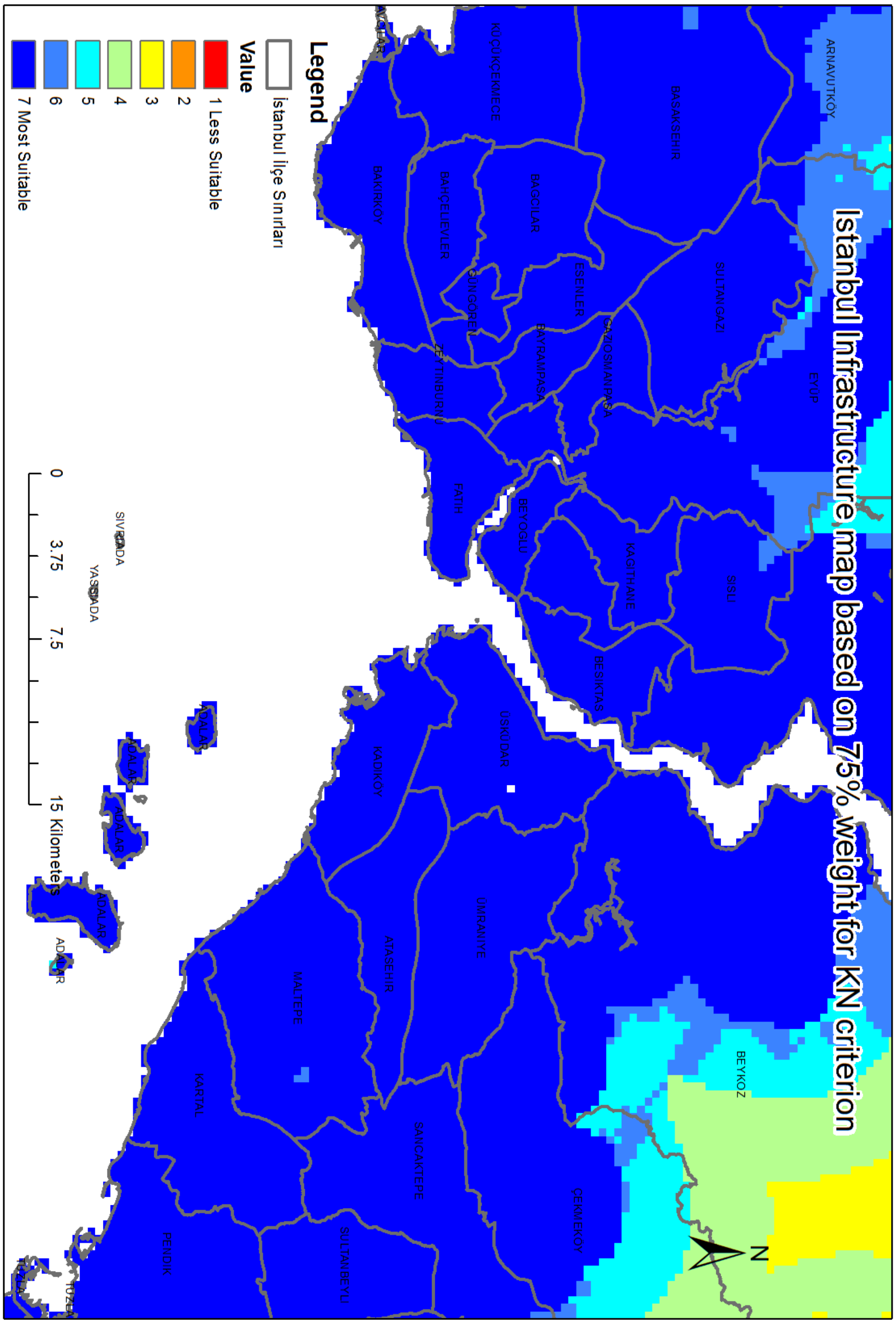

Figure A.139 : Istanbul Infrastructure map based on 75% weight for KN criterion

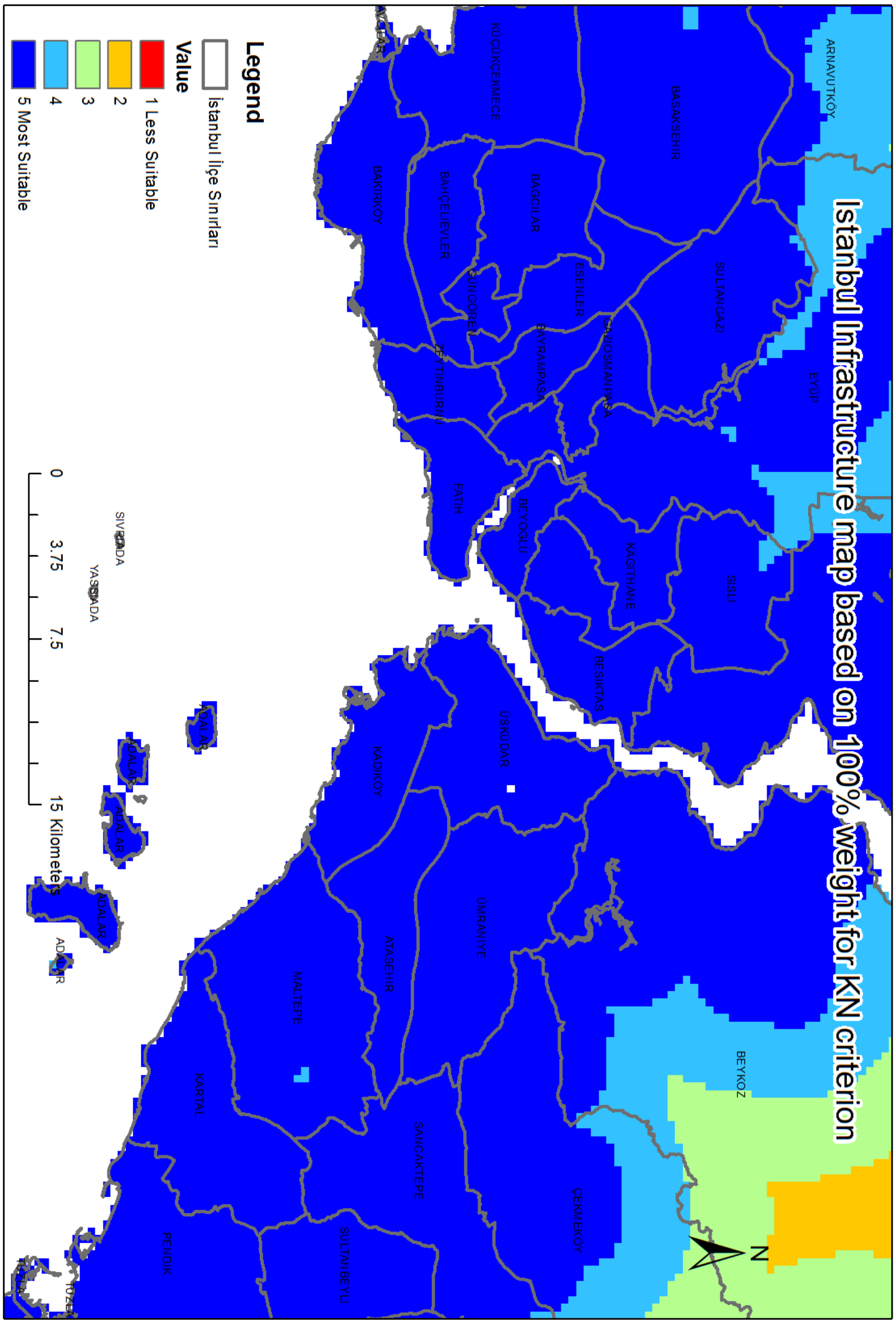

Figure A.140 : Istanbul Infrastructure map based on 100% weight for KN criterion

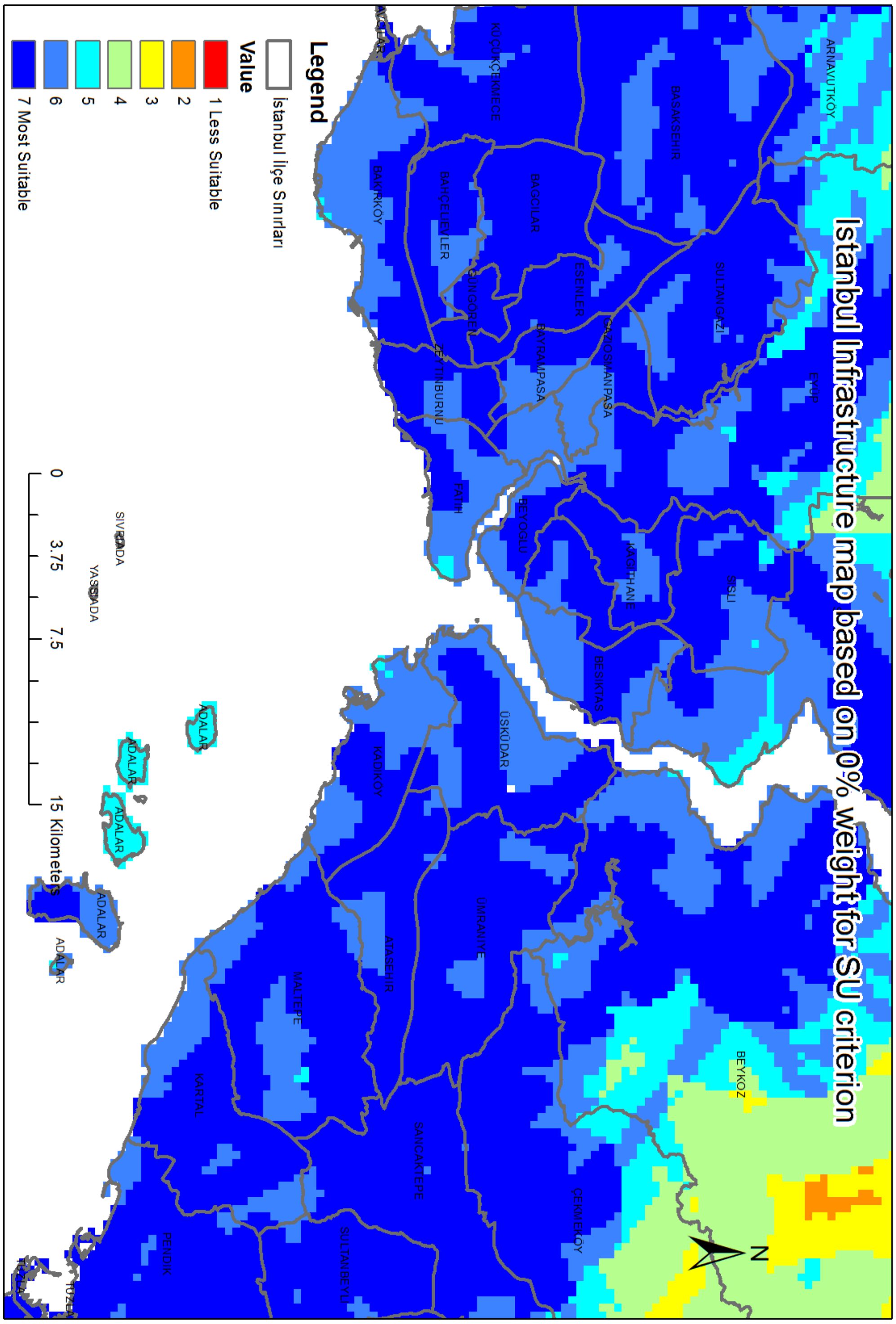

Figure A.141 : Istanbul Infrastructure map based on 0% weight for SU criterion

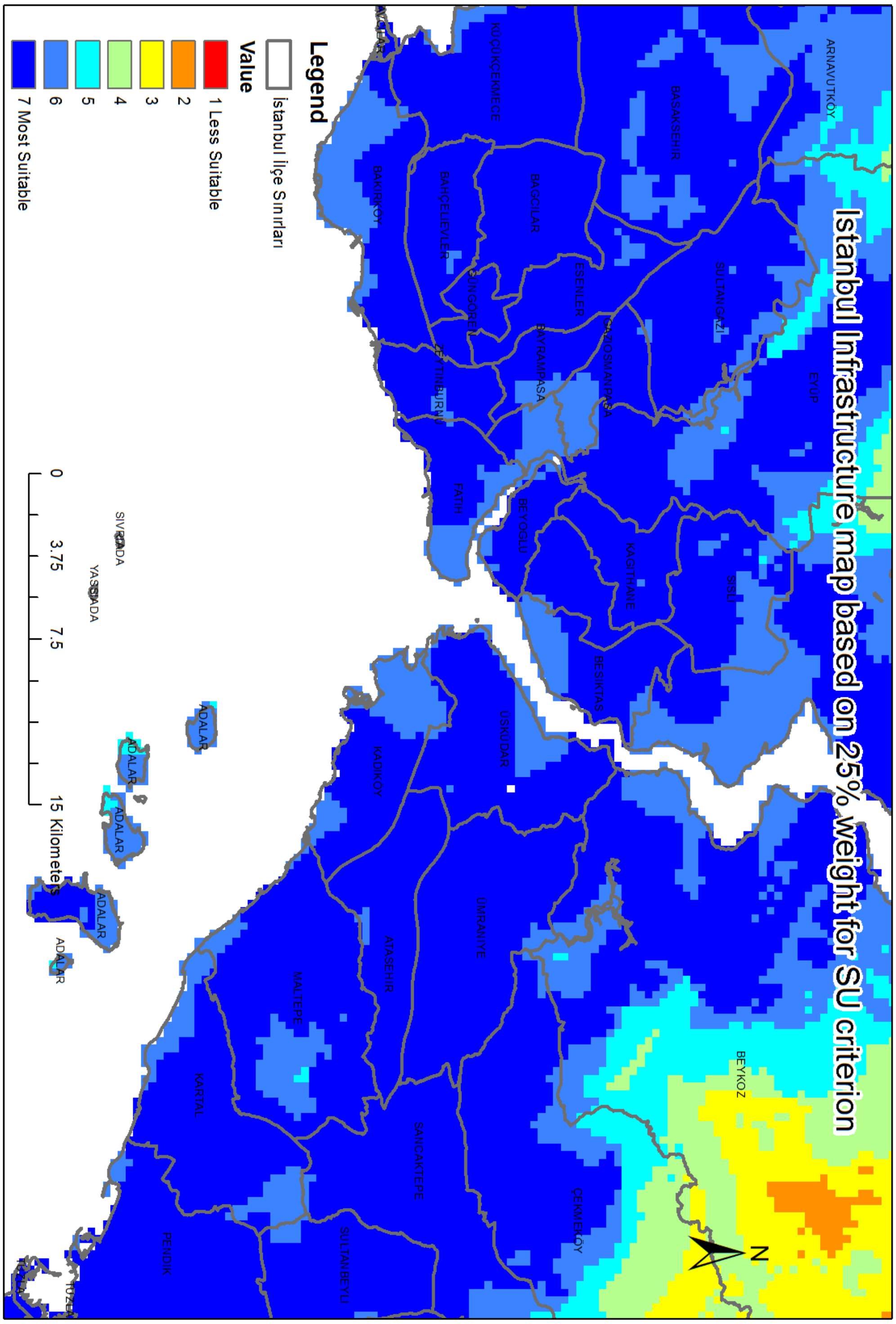

Figure A.142 : Istanbul Infrastructure map based on 25% weight for SU criterion

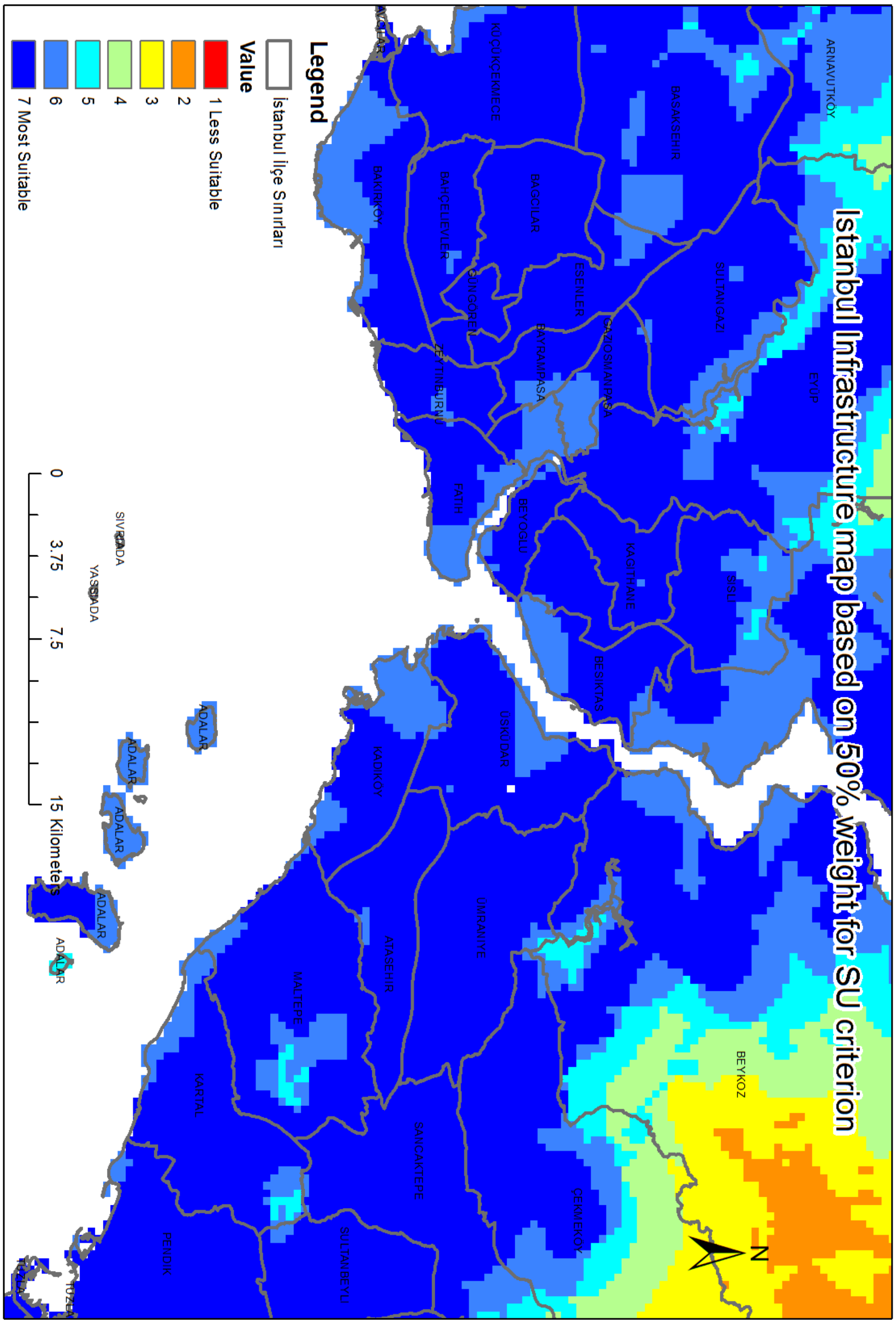

Figure A.143 : Istanbul Infrastructure map based on 50% weight for SU criterion

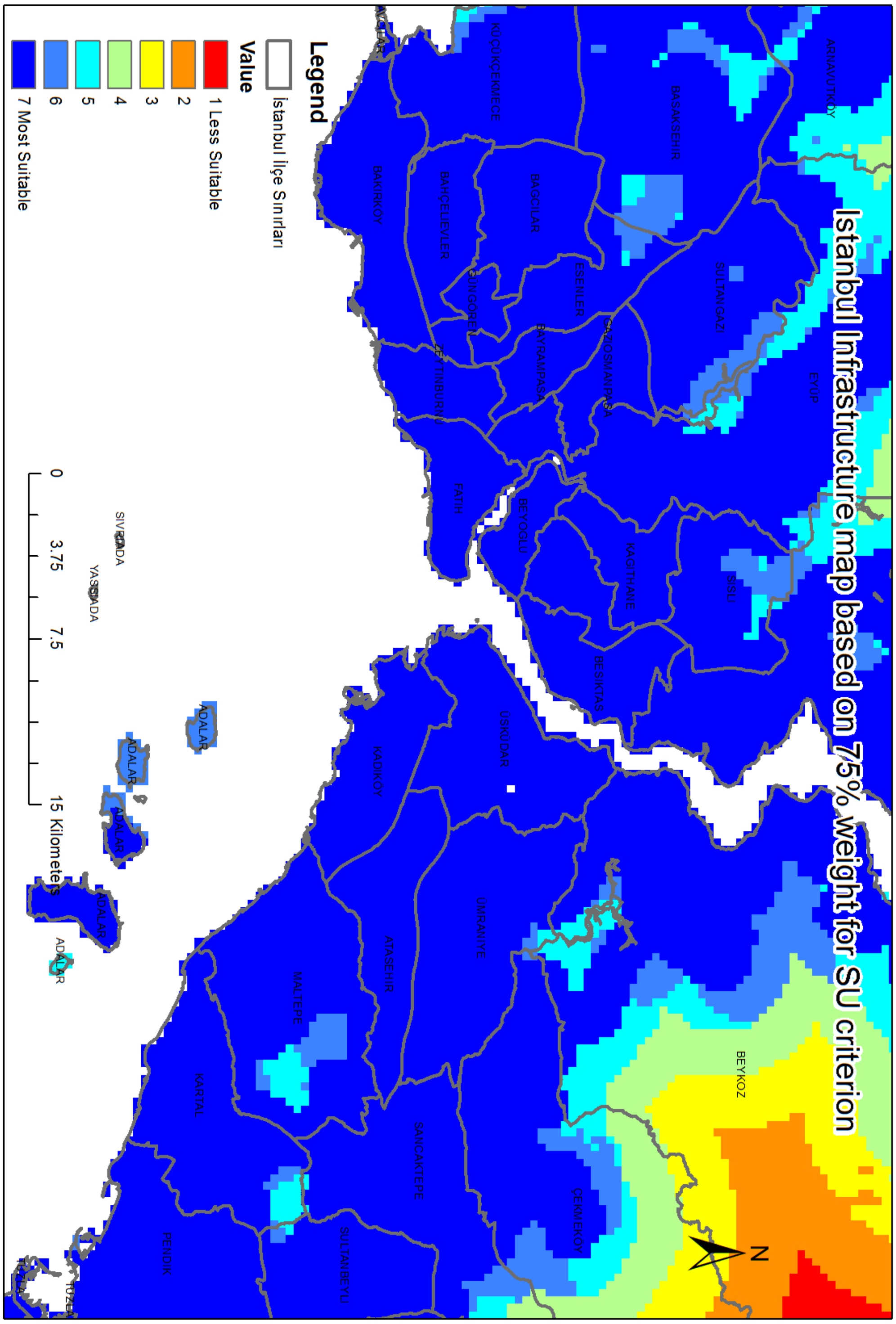

Figure A.144 : Istanbul Infrastructure map based on 75% weight for SU criterion

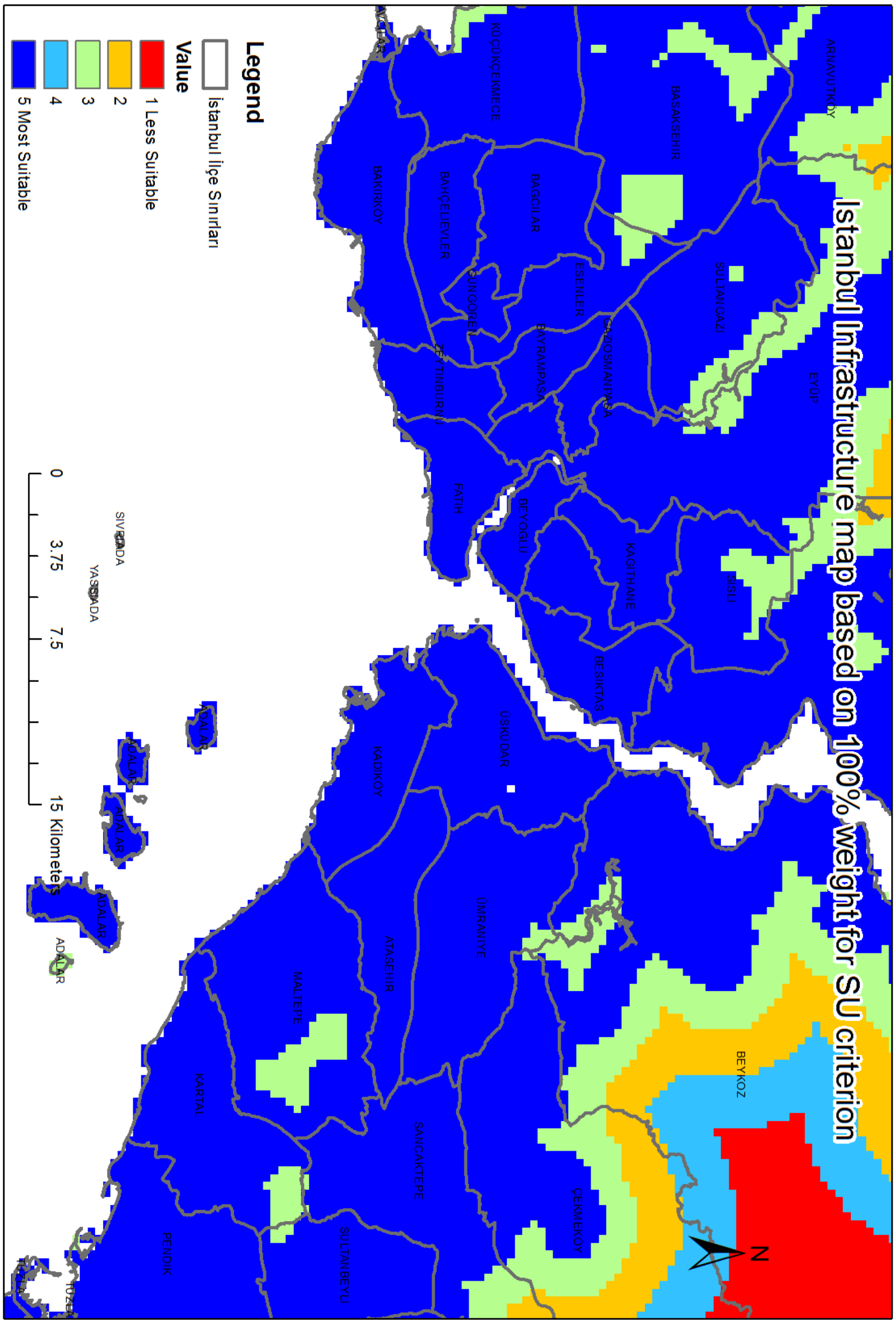

Figure A.145 : Istanbul Infrastructure map based on 100% weight for SU criterion

APPENDIX B - Tables

Table B.1: Sensitivity Analysis For AL (Infrastructure) Criterion

	Weight	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
AL	0.173	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	1.000
ER	0.207	0.250	0.225	0.200	0.175	0.150	0.125	0.100	0.075	0.050	0.025	0.000
TH	0.313	0.378	0.340	0.302	0.265	0.227	0.189	0.151	0.113	0.076	0.038	0.000
TO	0.095	0.115	0.104	0.092	0.081	0.069	0.058	0.046	0.035	0.023	0.011	0.000
KA	0.155	0.188	0.169	0.150	0.131	0.112	0.094	0.075	0.056	0.037	0.019	0.000
AK	0.057	0.069	0.062	0.056	0.048	0.042	0.034	0.028	0.021	0.014	0.007	0.000
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table B.2: Sensitivity Analysis For ER (Accessibility) Criterion

	Weight	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
AL	0.173	0.218	0.196	0.174	0.153	0.131	0.109	0.087	0.065	0.044	0.022	0.000
ER	0.207	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	1.000
TH	0.313	0.395	0.355	0.316	0.276	0.237	0.198	0.158	0.119	0.079	0.040	0.000
TO	0.095	0.120	0.108	0.096	0.084	0.072	0.060	0.048	0.036	0.024	0.012	0.000
KA	0.155	0.195	0.176	0.156	0.137	0.117	0.097	0.078	0.058	0.039	0.019	0.000
AK	0.057	0.072	0.065	0.058	0.050	0.043	0.036	0.029	0.022	0.014	0.007	0.000
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table B.3: Sensitivity Analysis For TH (Hazard) Criterion

	Weight	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
AL	0.173	0.252	0.227	0.202	0.176	0.151	0.126	0.101	0.076	0.050	0.025	0.000
ER	0.207	0.301	0.271	0.241	0.211	0.180	0.151	0.121	0.090	0.060	0.030	0.000
TH	0.313	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	1.000
TO	0.095	0.138	0.124	0.110	0.097	0.083	0.069	0.055	0.041	0.028	0.014	0.000
KA	0.155	0.226	0.203	0.181	0.158	0.136	0.113	0.090	0.068	0.045	0.023	0.000
AK	0.057	0.083	0.075	0.066	0.058	0.050	0.041	0.033	0.025	0.017	0.008	0.000
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table B.4: Sensitivity Analysis For TO (Topography) Criterion

	Weight	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
AL	0.173	0.191	0.172	0.153	0.134	0.114	0.096	0.077	0.057	0.038	0.019	0.000
ER	0.207	0.229	0.206	0.183	0.160	0.137	0.115	0.092	0.069	0.046	0.023	0.000
TH	0.313	0.346	0.311	0.277	0.242	0.208	0.173	0.138	0.104	0.069	0.034	0.000
TO	0.095	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	1.000
KA	0.155	0.171	0.154	0.137	0.120	0.103	0.085	0.068	0.051	0.034	0.018	0.000
AK	0.057	0.063	0.057	0.050	0.044	0.038	0.031	0.025	0.019	0.013	0.006	0.000
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table B.5: Sensitivity Analysis For KA (Capacity) Criterion

	Weight	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
AL	0.173	0.205	0.185	0.164	0.144	0.123	0.103	0.082	0.062	0.041	0.020	0.000
ER	0.207	0.245	0.221	0.196	0.172	0.147	0.123	0.098	0.073	0.049	0.025	0.000
TH	0.313	0.371	0.333	0.296	0.259	0.223	0.185	0.148	0.111	0.075	0.037	0.000
TO	0.095	0.112	0.101	0.090	0.078	0.067	0.056	0.045	0.034	0.022	0.011	0.000
KA	0.155	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	1.000
AK	0.057	0.067	0.060	0.054	0.047	0.040	0.033	0.027	0.020	0.013	0.007	0.000
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table B.6: Sensitivity Analysis For AK (Land Usage) Criterion

	Weight	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
AL	0.173	0.183	0.165	0.146	0.128	0.110	0.091	0.073	0.055	0.037	0.018	0.000
ER	0.207	0.220	0.198	0.176	0.154	0.132	0.110	0.088	0.066	0.044	0.022	0.000
TH	0.313	0.332	0.299	0.266	0.232	0.199	0.166	0.133	0.100	0.066	0.033	0.000
TO	0.095	0.101	0.091	0.081	0.071	0.061	0.051	0.040	0.030	0.020	0.010	0.000
KA	0.155	0.164	0.147	0.131	0.115	0.098	0.082	0.066	0.049	0.033	0.017	0.000
AK	0.057	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	1.000
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table B.7: Sensitivity Analysis For DP (Earthquake Hazard) Criterion

	Weight	0%	25%	50%	75%	100%
DP	0.074	0.0000	0.2500	0.5000	0.7500	1.0000
TS	0.074	0.0800	0.0600	0.0400	0.0200	0.0000
HY	0.132	0.1425	0.1065	0.0715	0.0360	0.0000
SB	0.132	0.1425	0.1065	0.0715	0.0360	0.0000
KM	0.227	0.2450	0.1840	0.1220	0.0610	0.0000
YN	0.361	0.3900	0.2930	0.1950	0.0970	0.0000
Total	1.000	1.0000	1.0000	1.0000	1.0000	1.0000

Table B.8: Sensitivity Analysis For TS (Tsunami Hazard) Criterion

	Weight	0%	25%	50%	75%	100%
DP	0.074	0.0800	0.0600	0.0400	0.0200	0.0000
TS	0.074	0.0000	0.2500	0.5000	0.7500	1.0000
HY	0.132	0.1425	0.1065	0.0715	0.0360	0.0000
SB	0.132	0.1425	0.1065	0.0715	0.0360	0.0000
KM	0.227	0.2450	0.1840	0.1220	0.0610	0.0000
YN	0.361	0.3900	0.2930	0.1950	0.0970	0.0000
Total	1.000	1.0000	1.0000	1.0000	1.0000	1.0000

Table B.9: Sensitivity Analysis For HY (Landslide Hazard) Criterion

	Weight	0%	25%	50%	75%	100%
DP	0.074	0.0850	0.0640	0.0425	0.0210	0.0000
TS	0.074	0.0850	0.0640	0.0425	0.0210	0.0000
HY	0.132	0.0000	0.2500	0.5000	0.7500	1.0000
SB	0.132	0.1520	0.1140	0.0760	0.0380	0.0000
KM	0.227	0.2620	0.1960	0.1310	0.0660	0.0000
YN	0.361	0.4160	0.3120	0.2080	0.1040	0.0000
Total	1.000	1.0000	1.0000	1.0000	1.0000	1.0000

Table B.10: Sensitivity Analysis For SB (Flood Hazard) Criterion

	Weight	0%	25%	50%	75%	100%
DP	0.074	0.0850	0.0640	0.0425	0.0210	0.0000
TS	0.074	0.0850	0.0640	0.0425	0.0210	0.0000
HY	0.132	0.1520	0.1140	0.0760	0.0380	0.0000
SB	0.132	0.0000	0.2500	0.5000	0.7500	1.0000
KM	0.227	0.2620	0.1960	0.1310	0.0660	0.0000
YN	0.361	0.4160	0.3120	0.2080	0.1040	0.0000
Total	1.000	1.0000	1.0000	1.0000	1.0000	1.0000

Table B.11: Sensitivity Analysis For KM (Chemical Hazard) Criterion

	Weight	0%	25%	50%	75%	100%
DP	0.074	0.0955	0.0720	0.0480	0.0240	0.0000
TS	0.074	0.0955	0.0720	0.0480	0.0240	0.0000
HY	0.132	0.1710	0.1280	0.0850	0.0430	0.0000
SB	0.132	0.1710	0.1280	0.0850	0.0430	0.0000
KM	0.227	0.0000	0.2500	0.5000	0.7500	1.0000
YN	0.361	0.4670	0.3500	0.2340	0.1160	0.0000
Total	1.000	1.0000	1.0000	1.0000	1.0000	1.0000

Table B.12: Sensitivity Analysis For YN (Fire Hazard) Criterion

	Weight	0%	25%	50%	75%	100%
DP	0.074	0.1160	0.0870	0.0580	0.0290	0.0000
TS	0.074	0.1160	0.0870	0.0580	0.0290	0.0000
HY	0.132	0.2065	0.1550	0.1030	0.0520	0.0000
SB	0.132	0.2065	0.1550	0.1030	0.0520	0.0000
KM	0.227	0.3550	0.2660	0.1780	0.0880	0.0000
YN	0.361	0.0000	0.2500	0.5000	0.7500	1.0000
Total	1.000	1.0000	1.0000	1.0000	1.0000	1.0000

Table B.13: Sensitivity Analysis For KR (Roads and Highways) Criterion

	Weight	0%	25%	50%	75%	100%
KR	0.542	0.000	0.250	0.500	0.750	1.000
DN	0.085	0.186	0.139	0.093	0.046	0.000
HV	0.140	0.306	0.230	0.153	0.077	0.000
DM	0.233	0.508	0.381	0.254	0.127	0.000
Total	1.000	1.000	1.000	1.000	1.000	1.000

Table B.14: Sensitivity Analysis For DN (Marine Ports) Criterion

	Weight	0%	25%	50%	75%	100%
KR	0.542	0.592	0.444	0.296	0.148	0.000
DN	0.085	0.000	0.250	0.500	0.750	1.000
HV	0.140	0.153	0.115	0.076	0.038	0.000
DM	0.233	0.255	0.191	0.128	0.064	0.000
Total	1.000	1.000	1.000	1.000	1.000	1.000

Table B.15: Sensitivity Analysis For HV (Heliport Stations) Criterion

	Weight	0%	25%	50%	75%	100%
KR	0.542	0.630	0.472	0.315	0.157	0.000
DN	0.085	0.099	0.075	0.049	0.025	0.000
HV	0.140	0.000	0.250	0.500	0.750	1.000
DM	0.233	0.271	0.203	0.136	0.068	0.000
Total	1.000	1.000	1.000	1.000	1.000	1.000

Table B.16: Sensitivity Analysis For DM (Railways) Criterion

	Weight	0%	25%	50%	75%	100%
KR	0.542	0.707	0.530	0.354	0.177	0.000
DN	0.085	0.111	0.083	0.055	0.028	0.000
HV	0.140	0.182	0.137	0.091	0.045	0.000
DM	0.233	0.000	0.250	0.500	0.750	1.000
Total	1.000	1.000	1.000	1.000	1.000	1.000

Table B.17: Sensitivity Analysis For IL (Communication) Criterion

	Weight	0%	25%	50%	75%	100%
IL	0.063	0.000	0.250	0.500	0.750	1.000
SU	0.233	0.249	0.186	0.124	0.062	0.000
KN	0.489	0.522	0.392	0.261	0.130	0.000
EL	0.152	0.162	0.122	0.081	0.041	0.000
GZ	0.063	0.067	0.050	0.034	0.017	0.000
Total	1.000	1.000	1.000	1.000	1.000	1.000

Table B.18: Sensitivity Analysis For SU (Drinking Water) Criterion

	Weight	0%	25%	50%	75%	100%
IL	0.063	0.082	0.062	0.041	0.021	0.000
SU	0.233	0.000	0.250	0.500	0.750	1.000
KN	0.489	0.638	0.478	0.319	0.159	0.000
EL	0.152	0.198	0.148	0.099	0.049	0.000
GZ	0.063	0.082	0.062	0.041	0.021	0.000
Total	1.000	1.000	1.000	1.000	1.000	1.000

Table B.19: Sensitivity Analysis For KN (Waste Water Lines) Criterion

	Weight	0%	25%	50%	75%	100%
IL	0.063	0.123	0.092	0.062	0.031	0.000
SU	0.233	0.456	0.343	0.228	0.114	0.000
KN	0.489	0.000	0.250	0.500	0.750	1.000
EL	0.152	0.298	0.223	0.148	0.074	0.000
GZ	0.063	0.123	0.092	0.062	0.031	0.000
Total	1.000	1.000	1.000	1.000	1.000	1.000

Table B.20: Sensitivity Analysis For EL (Electricity Lines) Criterion

	Weight	0%	25%	50%	75%	100%
IL	0.063	0.0740	0.0550	0.0370	0.0185	0.0000
SU	0.233	0.2750	0.2070	0.1380	0.0690	0.0000
KN	0.489	0.5770	0.4330	0.2880	0.1440	0.0000
EL	0.152	0.0000	0.2500	0.5000	0.7500	1.0000
GZ	0.063	0.0740	0.0550	0.0370	0.0185	0.0000
Total	1.000	1.000	1.000	1.000	1.000	1.000

Table B.21: Sensitivity Analysis For GZ (Gas Lines) Criterion

	Weight	0%	25%	50%	75%	100%
IL	0.063	0.067	0.050	0.033	0.017	0.000
SU	0.233	0.249	0.187	0.125	0.062	0.000
KN	0.489	0.522	0.391	0.261	0.130	0.000
EL	0.152	0.162	0.122	0.081	0.041	0.000
GZ	0.063	0.000	0.250	0.500	0.750	1.000
Total	1.000	1.000	1.000	1.000	1.000	1.000

Table B.22: Means and Standard Deviations For AL Parameter

Infrastructure's (AL) Weight	Mean	Standard Deviation
0.173	4.925	1.156
0.000	5.085	1.909
0.100	5.736	1.816
0.200	6.327	1.738
0.300	6.909	1.713
0.400	7.384	1.676
0.500	7.472	1.748
0.600	7.851	1.632
0.700	7.794	1.686
0.800	6.181	1.843
0.900	7.758	1.792
1.000	7.681	1.855

Table B.23: Means and Standard Deviations For ER Parameter

Accessibility's (ER) Weight	Mean	Standard Deviation
0.207	4.925	1.156
0.000	4.849	2.127
0.100	5.497	1.945
0.200	6.132	1.765
0.300	6.727	1.617
0.400	7.268	1.530
0.500	7.705	1.403
0.600	7.993	1.315
0.700	8.070	1.285
0.800	8.129	1.313
0.900	8.088	1.393
1.000	8.052	1.478

Table B.24: Means and Standard Deviations For TH Parameter

Hazard's (TH) Weight	Mean	Standard Deviation
0.313	4.925	1.156
0.000	7.227	1.624
0.100	7.303	1.744
0.200	6.982	1.836
0.300	6.273	1.761
0.400	5.499	1.732
0.500	4.727	1.770
0.600	3.889	1.821
0.700	3.027	1.912
0.800	2.368	1.941
0.900	1.977	1.977
1.000	1.970	2.129

Table B.25: Means and Standard Deviations For TO Parameter

Topography's (TO) Weight	Mean	Standard Deviation
0.095	4.925	1.156
0.000	5.565	1.959
0.100	6.213	1.743
0.200	6.819	1.567
0.300	7.388	1.393
0.400	7.813	1.241
0.500	8.062	1.125
0.600	8.200	1.005
0.700	8.273	1.913
0.800	8.159	0.804
0.900	7.883	0.586
1.000	7.880	0.495

Table B.26: Means and Standard Deviation For KA Parameter

Capacity's (KA) Weight	Mean	Standard Deviation
0.155	4.925	1.156
0.000	6.266	1.299
0.100	6.263	1.507
0.200	6.095	1.984
0.300	5.893	2.649
0.400	5.542	3.209
0.500	4.191	3.346
0.600	2.273	2.261
0.700	2.223	2.322
0.800	3.517	2.866
0.900	4.254	2.921
1.000	4.122	2.950

Table B.27: Means and Standard Deviation For AK Parameter

Land Usage's (AK) Weight	Mean	Standard Deviation
0.057	4.925	1.156
0.000	6.784	1.753
0.100	5.695	1.735
0.200	4.513	1.692
0.300	3.337	1.559
0.400	2.210	1.267
0.500	1.430	0.994
0.600	1.254	0.844
0.700	1.404	0.999
0.800	1.748	1.303
0.900	1.707	1.206
1.000	1.553	1.130

Table B.28: Means and Standard Deviation For DP Parameter

Earthquake Hazard (DP) Weight	Mean	Standard Deviation
0.074	2.949	1.183
0.000	2.767	1.301
0.250	3.387	0.946
0.500	4.010	0.800
0.750	4.632	0.962
1.000	5.252	1.323

Table B.29: Means and Standard Deviation For HY Parameter

Land Slide Hazard (HY) Weight	Mean	Standard Deviation
0.132	2.949	1.183
0.000	2.998	1.058
0.250	2.907	1.334
0.500	2.812	1.728
0.750	2.717	2.175
1.000	2.626	2.647

Table B.30: Means and Standard Deviation For KM Parameter

Chemical Hazard (KM) Weight	Mean	Standard Deviation
0.227	2.949	1.183
0.000	3.020	0.968
0.250	2.945	1.216
0.500	2.866	1.640
0.750	2.790	2.138
1.000	2.711	2.668

Table B.31: Means and Standard Deviation For SB Parameter

Flood Hazard (SB) Weight	Mean	Standard Deviation
0.132	2.949	1.183
0.000	2.998	1.058
0.250	2.907	1.334
0.500	2.812	1.728
0.750	2.717	2.175
1.000	2.626	2.647

Table B.32: Means and Standard Deviation For TS Parameter

Tsunami Hazard (TS) Weight	Mean	Standard Deviation
0.074	2.949	1.183
0.000	2.767	1.301
0.250	3.387	0.946
0.500	4.010	0.800
0.750	4.632	0.962
1.000	5.252	1.323

Table B.33: Means and Standard Deviation For YN Parameter

Fire Hazard (YN) Weight	Mean	Standard Deviation
0.361	2.949	1.183
0.000	3.885	1.550
0.250	3.239	1.283
0.500	2.592	1.082
0.750	1.946	0.987
1.000	1.299	1.029

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