ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

GIS AND BEST-WORST METHOD INTEGRATION FOR WASTEWATER TREATMENT PLANT SITE SELECTION

M.Sc. THESIS

Elif ÇELİKEL

Applied Informatics Department

Geographical Information Technologies Program

JULY 2024

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

GIS AND BEST-WORST METHOD INTEGRATION FOR WASTEWATER TREATMENT PLANT SITE SELECTION

M.Sc. THESIS

Elif ÇELİKEL
(706201022)

Applied Informatics Department

Geographical Information Technologies Program

Thesis Advisor: Prof. Dr. Turan ERDEN

JULY 2024

ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

ATIKSU ARITMA TESİSİ YER SEÇİMİ İÇİN CBS VE EN İYİ-EN KÖTÜ YÖNTEMİN ENTEGRASYONU

YÜKSEK LİSANS TEZİ

Elif ÇELİKEL
(706201022)

Bilişim Uygulamaları Anabilim Dalı

Coğrafi Bilgi Teknolojileri Programı

Tez Danışmanı: Prof Dr. Turan ERDEN

TEMMUZ 2024

Elif Çelikel, a M.Sc. student of ITU Graduate School student ID 706201022, successfully defended the thesis entitled "GIS AND BEST-WORST METHOD INTEGRATION FOR WASTEWATER TREATMENT PLANT SITE SELECTION", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor :	**Prof. Dr. Turan ERDEN** İstanbul Technical University	.....
Jury Members :	**Prof. Dr. Himmet KARAMAN** Istanbul Technical University	.....
	Prof. Dr. Arif Çağdaş AYDINOĞLU Gebze Technical University	.....

Date of Submission : 22.05.2024
Date of Defense : 01.07.2024

To my beloved family,

FOREWORD

Istanbul Technical University is an esteemed institution I have aspired to join since 2012. The realization of this aspiration with the completion of this thesis fills me with pride. Primarily, I would like to extend my heartfelt thanks to the determined that girl who relentlessly pursued this dream and consistently strived for better.

I would like to thank my advisor Assoc. Prof. Dr. Turan ERDEN. Despite his demanding schedule, he unfailingly offered his academic wisdom and encouragement throughout my master's studies. His wealth of knowledge has undeniably carried me forward.

I am deeply grateful to my dearly missed mentor, Zekai GÖRGÜLÜ, whose unwavering support throughout my Urban Planning education was invaluable, and who never hesitated to lend a hand during the toughest times. I also want to express my heartfelt appreciation to Ayşe PAŞALIOĞLU GÖKBAYRAK and İsmail GÜNAL. Their guidance during my undergraduate studies, enriched by their professional experience, has continually steered me towards improvement and success.

I wish to convey my deepest appreciation to my dear friend, Elçin SARI. Her steadfast support towards my academic and professional progression, ever since our paths crossed, has been invaluable. With her experience, profound knowledge, and boundless kindness, she has invariably furnished the assistance and sacrifices required. Notably, I am especially grateful to her during the challenging journey of my master's thesis, her patient guidance and relentless encouragement to surpass my own standards.

I would like to express my profound gratitude to my parents, Zeynep ÇELİKEL and Hasan ÇELİKEL, who indisputably deserve the highest commendation, as they have decisively stood by my side for 27 years. I extend my deepest appreciation for their generous and unconditional love, their unwavering assistance through life's challenges, and notably, their self-sacrifice and incessant striving towards my well-being throughout my educational journey. They play a huge role in the person I have become today.

Finally, I would like to greet everyone who has supported me at various stages of my life and helped me learn lessons.

July 2024

Elif Çellikel
(Urban Planner)

TABLE OF CONTENTS

Page

ABBREVIATIONS

AHP : Analytic Hierarchy Process
ANN : Artificial Neural Network
ANP : Analytic Network Process
BWM : Best-Worst Method
CI : Consistency Index
FAO : Food and Agriculture Organization of the United Nations
FHA : Fuzzy Hierarchical Analysis
GEM : Global Earthquake Model
GIS : Geographic Information Systems
MAUT : Multi-Attribute Utility Theory
MCDM : Multi Criteria Decision Making
RS : Remote Sensing
SEPA : Special Environmental Protection Areas
SFAHP : Spatial Fuzzy Analytic Hierarchy Process
TOPSIS : Technique for Order of Preference by Similarity to Ideal Solution
USGS : United States Geological Survey
WHO : World Health Organization
WLC : Weighted Linear Combination
WWF : World Wildlife Fund
WWTP : Wastewater Treatment Plant

SYMBOLS

ξ	**:** Highest inequality between best and worst criterion
a_{Bj}	**:** Comparison of best criterion to criterion j.
a_{jW}	**:** Comparison of worst criterion to criterion j.
a_{BW}	**:** Comparison between best and worst criterion
w	**:** Weight of the relevant criteria.

LIST OF TABLES

Page

LIST OF FIGURES

Page

GIS AND BEST-WORST METHOD INTEGRATION FOR WASTEWATER TREATMENT PLANT SITE SELECTION

SUMMARY

In today's evolving world, water scarcity poses a profound challenge to the underpinnings of sustainable existence and development. The strategic selection of locations for wastewater treatment plants (WWTPs) has surfaced as an indispensable component of the solution. This salient issue demands a comprehensive study that innovatively combines elements of environmental science, geography, and sustainable development. This study aims to pioneer the application of treated wastewater in agricultural practices, thereby offering a sustainable bridge between the escalating need for clean water resources and the relentless demands of agricultural production. At the core of our research lies a fundamental mission to identify and designate the most suitable and environmentally benign locations for WWTPs. Such a mission requires meticulous planning, comprehensive analysis, and innovative thinking. We have adopted a novel approach in our methodology that strives to strike a balance between maintaining ecological integrity and fostering agricultural productivity. This balance is not merely a theoretical construct, but a pragmatic goal aimed at ensuring that potential harm to the environment is minimized by the judicious selection of locations for the WWTPs. Simultaneously, their contribution to agricultural activities is maximized through the effective treatment and recycling of wastewater. This balance is indispensable in the relentless pursuit of sustainable solutions for water scarcity and agricultural sustainability. It ensures that the benefits derived from the WWTPs do not come at the expense of the environment, hence embodying the principle of sustainable development.

In order to effectively navigate the intricate array of criteria involved in the selection of suitable sites for WWTPs, we leverage the power of Geographic Information Systems. Geographic Information Systems, commonly referred to as GIS, is a sophisticated technological tool that has transformed the scope of spatial data analysis. It empowers users with the ability to manipulate, analyze, and visualize spatial data in ways that reveal patterns, relationships, and trends that might not be immediately apparent in the raw data. By integrating diverse data sets into a comprehensive, dynamic platform, GIS facilitates a greater depth of analytical insight, thereby enabling more informed decision-making processes. Its application in a variety of fields, ranging from environmental sciences to urban planning and public health, is a testament to its versatility and robustness as a tool for spatial problem-solving. It is not just a mapping tool, but a powerful analytical machine that can handle complex spatial queries, perform intricate computations, and generate insightful visualizations. In the context of water resource management and site selection for wastewater treatment plants, GIS provides the essential spatial perspective, highlighting patterns, and offering solutions that may not have been readily apparent without the assistance of this advanced technology. Thus, the importance of Geographic Information Systems in this study cannot be overstated.

Alonge with GIS, we employ a novel multi-criteria decision-making (MCDM) tool known as the Best-Worst Method (BWM). This methodology stands out for its ability to reduce the extensive pairwise comparisons often required in MCDM, thereby streamlining the decision-making process, and enhancing the reliability of comparisons. The BWM begins by identifying the best and worst criteria, which are then compared with other criteria to determine their relative importance. Through a series of pairwise comparisons, the method generates a set of weights for each criterion. This process is not only faster but also more intuitive than conventional MCDM methods, as it focuses on the most and least important criteria first, making the decision-making process more efficient. The weighting of criteria is a particularly important aspect of BWM. By assigning weights to each criterion, the method helps to prioritize and focus on the most important factors in the decision-making process. This aspect of BWM is particularly crucial in our work, as it enables us to assign priority to the most critical criteria in determining the most suitable and sustainable locations for wastewater treatment plants. By incorporating the Best-Worst Method, we are able to increase the efficiency and reliability of our decision-making process, leading to more precise and accurate outcomes. The transformative power of integrating GIS and BWM in our work underscores the potential of these innovative methodologies in addressing the pressing challenges of water scarcity and agricultural sustainability.

Within the scope of this comprehensive study, an evaluation for site selection was conducted based on seven criteria: slope, elevation, distance from road network, land use, distance from water resources, distance from settlement areas, and soil type. To ensure the utmost accuracy in the evaluation process, the expert opinion was actively sought to assign appropriate weights to each of these criteria. This was done within the structured framework of the Best Worst Method, a widely recognized and scientifically sound approach to multicriteria decision making. Upon careful analysis and comparison, it was discovered that the distance to water resources stood out as the most important criterion, carrying the highest weight. Following closely was the criterion related to the distance from settlements, which emerged as a secondary yet significantly important factor in the site selection process. On the other hand, the criterion related to land use was ascertained to carry the least weight when compared to the other criteria. Despite its lower importance, it still formed an integral part of the comprehensive evaluation process for site selection.

The focus of this study is the Konya Closed Basin, a region of substantial importance due to its considerable contribution to Turkey's agricultural activity, which stands in stark contrast to its limited water resources. The Konya Closed Basin's distinctive characteristics, coupled with the challenges it presents, render it an optimal locale for conducting our research. This region not only allows us to examine our theoretical constructs in a tangible, real-world context, but also to delve deeper into the complexities that come with managing scarce water resources in an agriculturally intensive area.The insights gleaned from this study will be useful when it comes to both the establishment of new facilities and the evaluation of existing wastewater treatment plant (WWTP) locations within the confines of the Konya Closed Basin. By scrutinizing these aspects, we aim to facilitate better decision-making processes related to water management, and thus contribute to more sustainable practices in the region.

This research could very well echo beyond the Konya Closed Basin and potentially influence policymaking in other regions facing similar challenges.

As a result, the suitability analysis of the Konya Closed Basin for wastewater treatment plant (WWTP) construction reveals that 27.9% of the area is unsuitable, while 42.5% is moderately suitable and 19.5% highly suitable. The unsuitable areas are primarily concentrated around Tuz Lake and Beyşehir Lake. The analysis also shows that of the 24 existing WWTPs, only three are in highly suitable areas, while ten are in unsuitable areas. Future site selection should focus on high or moderate suitability areas, considering proximity to agricultural lands for potential irrigation use, while ensuring effective treatment to avoid contamination.

Through this pioneering study, we have managed to provide more than just a robust and comprehensive roadmap for the efficient establishment, operation, and assessment of wastewater treatment plants. Our work serves as a blueprint for future initiatives, highlighting the transformative potential and far-reaching implications of integrating Geographic Information System (GIS) and Best-Worst Method (BWM) in modern environmental management practices. This integration stands as a testament to the power of innovation and cutting-edge technology in addressing some of the most pressing and significant environmental challenges we face today. By incorporating GIS and BWM, we are able to streamline processes, improve accuracy, and ultimately, enhance the effectiveness of wastewater management. In doing so, it provides a guiding light towards a more sustainable future where issues like water scarcity are no longer a looming threat but are instead relegated to the annals of history. This vision of the future, one where water is abundant and accessible to all, is a goal we believe is within our grasp, and one that this study brings us one step closer to achieving.

ATIKSU ARITMA TESİSİ YER SEÇİMİ İÇİN CBS VE EN İYİ-EN KÖTÜ YÖNTEMİ ENTEGRASYONU

ÖZET

Günümüzün gelişen dünyasında su kıtlığı, sürdürülebilir kalkınmanın temelleri için bir zorluk teşkil etmektedir. Bu kapsamda Atıksu arıtma tesisleri (AAT) için stratejik yer seçimi, çözümün vazgeçilmez bir bileşeni olarak ortaya çıkmıştır. Bu önemli konu, çevre bilimi, coğrafya ve sürdürülebilir kalkınma unsurlarını yenilikçi bir şekilde birleştiren kapsamlı bir çalışma gerektirmektedir ve buu çalışma ile birlikte arıtılmış atık suyun tarımsal uygulamalarda kullanılmasına öncülük edilmesi ve böylece artan temiz su kaynakları ihtiyacı ile tarımsal üretimin arasında sürdürülebilir bir köprü kurulması amaçlanmaktadır. Araştırmamızın özünde, AAT'ler için en uygun ve çevreye zarar vermeyen yerleri belirleme ve tayin etme gibi temel bir misyon yatmaktadır. Bu misyon beraberinde titiz bir planlama, kapsamlı analiz ve yenilikçi düşünce gerektirmektedir. Metodolojimizde ekolojik bütünlüğün korunması ile tarımsal verimliliğin artırılması arasında bir denge kurmaya çalışan yeni bir yaklaşım benimsedik. Bu denge sadece teorik bir yapı değil, aynı zamanda AAT'lerin yerlerinin mantıklı bir şekilde seçilmesiyle çevreye verilen potansiyel zararın en aza indirilmesini sağlamayı amaçlayan pragmatik bir hedeftir. Bu doğrultuda atık suyun etkili bir şekilde arıtılması ve geri dönüştürülmesi beraberinde tarımsal faaliyetlere olan katkıyı da en üst düzeye çıkaracaktır. Bu hassas dengenin sağlanması, su kıtlığı ve tarımsal sürdürülebilirlik için bir çözümler arayışında vazgeçilmezler arasındadır ve AAT'lerden elde edilen faydaların çevreye zarar vermemesini, dolayısıyla sürdürülebilir kalkınma ilkesinin somutlaştırılmasını sağlamaktadır.

AAT'ler için uygun sahaların seçiminde yer alan karmaşık kriterler dizisini etkili bir şekilde yönlendirmek için Coğrafi Bilgi Sistemlerinin gücünden yararlandık. CBS, mekansal veri analizinin kapsamını dönüştüren sofistike bir teknolojik araçtır. Kullanıcılara, ham verilerde hemen görülemeyebilecek kalıpları, ilişkileri ve eğilimleri ortaya çıkaracak şekilde mekansal verileri manipüle etme, analiz etme ve görselleştirme becerisi kazandırır. Coğrafi Bilgi Sistemleri ile farklı veri setlerini kapsamlı ve dinamik bir platforma entegre ederek daha derin bir analitik kavrayış sağlanabilmekte ve böylece daha bilinçli karar alma süreçlerine olanak tanınabilmektedir. Çevre bilimlerinden şehir planlama ve kamu sağlığına kadar çeşitli alanlarda uygulanması, mekansal problem çözme aracı olarak çok yönlülüğünün ve sağlamlığının bir kanıtıdır. Sadece bir haritalama aracı değil, aynı zamanda karmaşık mekansal sorguları ele alabilen, karmaşık hesaplamalar yapabilen ve anlayışlı görselleştirmeler üretebilen güçlü bir analitik makinedir. Su kaynakları yönetimi ve atık su arıtma tesisleri için yer seçimi bağlamında CBS, temel mekansal perspektifi sağlar, kalıpları vurgular ve bu gelişmiş teknolojinin yardımı olmadan kolayca görülemeyecek çözümler sunar. Dolayısıyla, Coğrafi Bilgi Sistemlerinin bu çalışmadaki önemi yadsınamaz.

CBS ile birlikte, Best-Worst Method (En İyi-En Kötü Yöntemi) olarak bilinen ve nispeten yeni ortaya çıkmış bir çok kriterli karar verme aracını kullandık. Bu metodoloji, ÇKKV'de sıklıkla gerekli olan kapsamlı ikili karşılaştırmaları azaltma, böylece karar verme sürecini kolaylaştırma ve karşılaştırmaların güvenilirliğini artırma becerisiyle öne çıkmaktadır. BWM, en iyi ve en kötü kriterlerin belirlenmesiyle başlar ve bu kriterler daha sonra göreceli önemlerini belirlemek için diğer kriterlerle karşılaştırılır. Bir dizi ikili karşılaştırma yoluyla, yöntem her kriter için bir dizi ağırlık oluşturur. Bu süreç geleneksel ÇKKV yöntemlerine göre hem daha hızlı hem de daha sezgiseldir, çünkü öncelikle en önemli ve en önemsiz kriterlere odaklanarak karar verme sürecini daha verimli hale getirir. Kriterlerin ağırlıklandırılması BWM'nin özellikle önemli bir yönüdür ve bu yöntem her bir kritere ağırlık atayarak, karar verme sürecinde en önemli faktörlerin önceliklendirilmesine yardımcı olmaktadır. BWM, atıksu arıtma tesisleri için en uygun ve sürdürülebilir konumların belirlenmesinde en kritik kriterlere öncelik vermemizi sağladığından, methodun bu yönü bizim çalışmamızda özellikle önem arz etmektedir. Best Worst Method'u dahil ederek karar verme sürecimizin verimliliğini ve güvenilirliğini arttırarak, daha kesin ve doğru sonuçlar elde etmekteyiz. Bununla beraber CBS ve BWM'yi çalışmalarımıza entegre etmenin dönüştürücü gücü, bu yenilikçi metodolojilerin su kıtlığı ve tarımsal sürdürülebilirlik gibi acil zorlukları ele alma potansiyelinin altını çizmektedir.

Bu çalışma kapsamında yer seçimi için; eğim, yükseklik, yol ağına uzaklık, arazi kullanımı, su kaynaklarına uzaklık, yerleşim alanlarına uzaklık ve toprak tipi olmak üzere yedi kriter temel alınarak bir değerlendirme yapılmıştır. Değerlendirme sürecinde en yüksek doğruluğu sağlamak için, bu kriterlerin her birine uygun ağırlıkları atamak üzere uzman görüşüne aktif olarak başvurulmuştur. Bu, çok ölçütlü karar vermede yaygın olarak tanınan ve bilimsel olarak sağlam bir yaklaşım olan En İyi En Kötü Yönteminin yapılandırılmış çerçevesi içinde yapılmıştır. Dikkatli bir analiz ve karşılaştırma sonucunda, su kaynaklarına olan mesafenin en önemli kriter olarak öne çıktığı ve en yüksek ağırlığı taşıdığı görülmüştür. Hemen ardından gelen yerleşim yerlerine uzaklık kriteri ise ikincil ancak yer seçimi sürecinde önemli bir faktör olarak ortaya çıkmıştır. Öte yandan, arazi kullanımıyla ilgili kriterin diğer kriterlere kıyasla en az ağırlığa sahip olduğu tespit edilmiştir. Düşük önemine rağmen, yine de yer seçimi için kapsamlı değerlendirme sürecinin ayrılmaz bir parçasını oluşturmuştur.

Çalışmanın odak noktası ise Türkiye'nin tarımsal faaliyetlerine önemli katkısı nedeniyle büyük önem taşıyan ama sınırlı su kaynaklarıyla tam bir zıtlık oluşturan Konya Kapalı Havzası'dır. Konya Kapalı Havzası'nın kendine has özellikleri ve karşılaştığı zorluklar, bu bölgeyi araştırmamızı yürütmek için en uygun yer haline getirmektedir. Bu bölge, sadece araştırmamızı gerçek dünya bağlamında incelememize değil, aynı zamanda tarımsal açıdan yoğun bir bölgede kıt su kaynaklarını yönetmenin getirdiği karmaşıklıkları daha derinlemesine incelememize de olanak tanımaktadır. Bu çalışmadan elde edilen bilgiler, Konya Kapalı Havzası sınırları içinde hem yeni tesislerin kurulması hem de mevcut atık su arıtma tesisi (AAT) konumlarının değerlendirilmesi söz konusu olduğunda faydalı olacaktır. Bu hususları inceleyerek, su yönetimi ile ilgili daha iyi karar alma süreçlerini kolaylaştırmayı ve böylece bölgede daha sürdürülebilir uygulamalara katkıda bulunmayı amaçladık. Bu araştırma, Konya Kapalı Havzası'nın ötesinde benzer zorluklarla karşılaşan diğer bölgelerdeki politika oluşturma süreçlerini de

etkileyebilmektedir. Yapılan uygunluk analizinin sonuçları ise Konya Kapalı Havzası'nın atıksu arıtma tesisi (AAT) inşaatı için, alanın %27,9'unun uygun olmadığını, %42,5'inin orta derecede uygun olduğunu ve %19,5'inin yüksek derecede uygun olduğunu ortaya koymaktadır. Uygun olmayan alanlar öncelikle Tuz Gölü ve Beyşehir Gölü çevresinde yoğunlaşmaktadır. Analiz sonuçları ayrıca alanda mevcut olan 24 atıksu arıtma tesisinden sadece üçünün son derece uygun alanlarda, onunun ise uygun olmayan alanlarda inşa edildiğini göstermektedir. Gelecekteki yer seçimi, potansiyel sulama kullanımı için tarım arazilerine yakınlığı göz önünde bulundurarak yüksek veya orta uygunluktaki alanlara odaklanmalı ve kirlenmeyi önlemek için etkili arıtma sağlamalıdır.

Bu çalışma sayesinde, atık su arıtma tesislerinin verimli bir şekilde kurulması, işletilmesi ve değerlendirilmesi için sağlam ve kapsamlı bir yol haritasından daha fazlasını sunmayı başardık. Çalışmamız, modern çevre yönetimi uygulamalarında Coğrafi Bilgi Sistemi (CBS) ve En İyi-En Kötü Yöntemi entegrasyonunun dönüştürücü potansiyelini ve geniş kapsamlı etkilerini vurgulayarak gelecekteki girişimler için bir plan görevi görmektedir. Bu entegrasyon, günümüzde karşılaştığımız en acil ve önemli çevresel zorluklardan bazılarının ele alınmasında inovasyonun ve en son teknolojinin gücünün bir kanıtıdır. CBS ve BWM'yi bir araya getirerek süreçleri kolaylaştırabilir, doğruluğu artırabilir ve nihayetinde atık su yönetiminin etkinliğini artırabiliriz. Bunu yaparken, su kıtlığı gibi sorunların artık yaklaşan bir tehdit olmaktan çıkıp tarihe karıştığı daha sürdürülebilir bir geleceğe doğru yol gösterici bir ışık sağlıyor. Suyun bol ve herkes için erişilebilir olduğu bu gelecek vizyonu, elimizin altında olduğuna inandığımız ve bu çalışmanın bizi ulaşmaya bir adım daha yaklaştırdığı bir hedeftir.

1. INTRODUCTION

Accessible and reliable water sources are essential for the sustenance of all living beings. These sources not only provide drinking water for human consumption but also support agricultural activities, industrial operations, and ecosystem functioning [1]. However, we are currently witnessing a progressive decline in the accessibility of these essential resources. This alarming pattern of declining water accessibility can be attributed to several key causes.

One of these causes is population growth since the rising global population results in an increased need for water. This is accompanied by rapid urbanization, which frequently emphasizes expansion at the expense of sustainability, resulting in substantial water loss. This problem is also influenced by improved living conditions. With the progress of civilizations and the enhancement of living conditions, there is a tendency for individual water consumption to rise. This is particularly accurate in industrialized nations, where elevated living standards frequently correspond to elevated water use [2].

In addition, the agriculture industry is an enormous consumer of water resources. Agricultural practices such as irrigation and animal production have a significant water consumption. The industrial sector, because of its advancements and high demand, puts significant pressure on water resources. Moreover, the increasing accumulation of pollutants in water sources results in the deterioration of available water resources. Industrial facilities frequently release untreated waste into water bodies, resulting in contamination and rendering the water unsuitable for usage. Ultimately, the modification of climate, generally referred to as climate change, has a significant and far-reaching effect on water supplies. Alterations in meteorological patterns can result in periods of prolonged dryness, excessive precipitation, and many other exceptional occurrences, all of which have the potential to disturb the accessibility of uncontaminated, useable water [2].

Considering all these factors, it is crucial to develop and execute plans that can ensure long-term sustainability and effective management of our unique freshwater resources. When doing a comprehensive analysis of water consumption patterns at both global and national scales, it becomes evident that the agriculture sector is a major consumer of water resources. Simultaneously, the management of water usage in agricultural practices is of greatest significance, as it is often utilized without conscious consideration, particularly in underdeveloped nations.

Given the present circumstances, the utilization of treated wastewater emerges as a notably effective and environmentally friendly alternative. The utilization of treated wastewater for agricultural irrigation has significant promise for sustainable resource management. Many irrigated agricultural areas are supplied with water from wastewater that has undergone treatment, is in its raw state, or has been slightly diluted. This can be either a direct or indirect source. Multiple scientific studies have confirmed that utilizing treated wastewater in agricultural activities not only yields considerable economic and environmental advantages, but also holds the potential to greatly augment agricultural productivity [3].

Nevertheless, it is crucial to use precautions while selecting treatment techniques for wastewater recovery and during irrigation procedures. The presence of pathogenic microorganisms in wastewater is associated with possible health concerns. Moreover, the presence of pollutants in wastewater may have adverse impacts on the soil and crops' well-being. Therefore, it is imperative to consider and effectively deal with these elements to guarantee secure and enduring procedures [3].

1.1 Purpose of Thesis

Water is a fundamental resource for life and its sustainable management is key to our future. Given its significant water use, agriculture poses a distinctive challenge and opportunity in the attempt to save freshwater. The most significant of the changes that may be made is the use of treated water instead of conventional water in agricultural activities, which is an alternative worth seriously considering. The use of treated water in this way provides a viable alternative for irrigation and other agricultural applications, reducing the strain on our water supply [4].

In this scope, the primary objective of this research is to investigate the essential process of determining the most optimal and environmentally friendly location for the construction of wastewater treatment facilities. By doing so, this study aims to enhance the sustainability of our valuable water resources. It involves a comprehensive analysis of various factors including environmental, geographical, and socio-economic considerations.

The most effective method for examining multiple variables to determine the optimal site selection is by combining geographic information systems (GIS) with multi-criteria decision-making methods. A wide range of MCDM methodologies have been applied in many sectors to conduct site selection studies. In fact, the Analytic Hierarchy Process (AHP) approach is one of the most often utilized strategies for selecting wastewater treatment plant sites. However, this study goes beyond the traditional use of AHP, introducing the Best-Worst technique to provide an alternative perspective to the existing literature. This technique allows for a more nuanced understanding of the various factors at play in site selection, further enriching the process and enhancing the quality of the final decision.

The findings of this research will offer essential knowledge and resources for policy makers, urban planners, and environmental conservationists in their attempt at establishing sustainable water resource management. Furthermore, the decision to utilize treated wastewater in agricultural practices, an industry that plays a significant role in the depletion of water resources, might be greatly affected by geographical considerations. This is because the choice of location is a crucial factor in determining the feasibility and sustainability of such an approach. Not only does it influence the logistical aspects, such as the transportation and distribution of treated wastewater, but it also impacts the agricultural productivity and the overall efficiency of water use. Hence, careful planning and consideration are necessary when deciding where to implement this potentially beneficial practice.

1.2 Study Area

The Konya Closed Basin is situated in the southern central part of the Central Anatolia Region, spanning from 36°51' to 39°29' north latitude and 31°36' to 34°52' east longitude. The region is next to Sakarya and Kızılırmak to the north, Kızılırmak and Seyhan to the east, the Eastern Mediterranean to the south, and the Antalya and

Akarçay basins to the west. The provinces of Aksaray, Ankara, Antalya, Isparta, Mersin, Konya, Karaman, Nevşehir, and Niğde are situated inside the basin. The Konya Closed Basin is one of the 25 river basins in Turkey, covering around 4,980,534 hectares, which represents 7% of the country's total surface area [5].

The Konya Plain covers a substantial portion of the basin. The mountains around the plain impede the flow of water from the basin into the sea. The Konya basin is a unique closed basin that does not drain its waters into the ocean, a rarity worldwide.

Due to its geographical location, Konya Closed Basin has minimal rainfall, making it one of the places with the lowest precipitation. Additionally, just 2% of Turkey's surface water resources are located inside the limits of this basin. Conversely, due to its size and enclosed nature, this area possesses almost 17% of Turkey's total groundwater potential. Given the limited availability of water resources in the study, almost 90% of the water in the basin is allocated for agricultural irrigation [6].

The Konya Closed Basin, while having less than 4% of Türkiye's overall water potential, accounts for 12% of the total agricultural fields and 16% of the irrigated areas in Türkiye [6]. Mainly, due to this very reason, the area was chosen as the primary focus for this research study. The area's distinct characteristics and unique features made it an ideal location for an in-depth analysis. Moreover, the presence of 24 wastewater treatment plants within the area [4][5], presents a great opportunity to determine how many are situated in suitable locations.

Figure 1.1: Map of Konya Closed Basin.

2. LITERATURE REVIEW

In this chapter, several fundamental questions relating to wastewater treatment plants are explored. An understanding of what wastewater treatment plants are and why it is essential to treat wastewater is provided. The advantages and disadvantages that come with utilizing this treated wastewater are delved into, providing a balanced perspective on the matter. Legal regulations that govern the treatment and recovery of wastewater are also discussed. This encompasses both a national and international perspective, allowing for a broader understanding of the subject matter. A thorough review of the existing studies present in the literature is conducted following this. The focus of this examination is on understanding the methods used for site selection of wastewater treatment plants and the purpose for which these methods were employed. To conclude the chapter, the most preferred multi-criteria decision-making methods for site selection, as drawn from the literature, are reviewed. Moreover, the Best-Worst Method is also introduced. This method, which is aimed to be utilized in this study, is discussed in depth, providing readers with a comprehensive understanding of its workings and its application to the rest of the chapter.

2.1 Wastewater Treatment Plant

While the proportion of clean water resources in global water usage remains relatively small, the importance of ensuring their long-term sustainability cannot be overstated. Clean water is a fundamental resource necessary for human life, agricultural activities, and the functioning of various industries. However, the availability of this precious resource is being threatened by global phenomena such as climate change and environmental pollution. These factors are leading to a reduction in clean water supplies, thereby making it harder for people to access fresh drinking water. Therefore, it becomes obvious that just safeguarding our existing water supplies is insufficient. It needs to be taken a step further and became a necessity to ensure the recycling and reuse of used water [7].

Wastewater is essentially water that has been altered, either partially or completely, due to a variety of activities. These activities can be of a domestic nature, such as household chores, or they can be industrial processes that require the use of water. Agricultural activities also contribute to the generation of wastewater, as water used for irrigation often picks up fertilizers and pesticides, thus changing its original composition. Additionally, there are other kinds of activities that can lead to the production of wastewater. For instance, rainwater that falls in residential areas often transforms into surface or subsurface flow, picking up pollutants and contaminants along its path, thereby becoming wastewater [8].

Along with this, wastewater treatment facilities have developed. The main purpose of wastewater treatment plants is to mitigate the harmful impacts of wastewater, which can be contaminated with a range of pollutants including physical, biological, chemical, and radioactive substances. These plants work to thoroughly cleanse this wastewater, removing or neutralizing these pollutants, to safeguard the surrounding environment [8].

After treatment, wastewater becomes a valuable resource that can be repurposed for a variety of applications. In the agricultural sector, treated wastewater can serve as a reliable and sustainable source of irrigation water, providing essential hydration for crops. In urban settings, treated wastewater can be used in several practical ways. It can be used for firefighting, providing an essential resource for managing and controlling fires in urban areas. It can also be used for dust control, reducing the levels of dust in the air, and contributing to cleaner and healthier urban environments. Other urban uses include serving as a source of siphon water, aiding in the melting of snow during cold weather conditions, and being used for car washing operations. Furthermore, treated wastewater is also beneficial for visual and environmental purposes. It can be used to create or maintain aesthetic features such as man-made lakes or fountains, and it plays a vital role in supporting wetland habitats and other ecosystems that rely on a consistent water source [7].

Wastewater treatment and reuse offer several primary advantages. Some examples of these advantages include: [2]

By preventing the release of treated wastewater into inland waterways such as lakes, ponds, rivers, and seas, there will be no extra pollution burden on these water

resources. Consequently, the integrity of other water sources, such as groundwater and surface water, will remain uncompromised.

Specifically in the case of agricultural irrigation, sectors that demand a significant amount of water, the replacement of natural water resources with treated wastewater could result in considerable conservation of clean water resources. This would be a substantial step towards a more sustainable use of our water supply.

The utilization of the nitrogen and minerals found inside treated wastewater for agricultural irrigation is another benefit. This can effectively reduce the need for additional, often expensive, fertilizers and in turn enhance crop productivity. It represents a form of recycling and sustainable farming that can contribute to a more balanced ecosystem.

The return of clean water, through the process of treating wastewater and reusing it, would have a ripple effect, enhancing the overall national economy. It would reduce expenditure on water purification and would also contribute to the conservation of our environment.

Figure 2.1: Wastewater Treatment Plant in Manisa.

Figure 2.2: Wastewater Treatment Plant in Mexico.

2.1.1 Use of treated wastewater in agricultural irrigation

The purpose of reusing wastewater in agricultural irrigation is to fulfill irrigation water requirements while safeguarding the environment from harmful effects and maintaining the health and safety of producers and consumers. Urban wastewater is primarily used for agricultural irrigation. Conversely, most industrial wastewater is not suitable for irrigation due to the toxic compounds it contains [7].

The use of treated wastewater for agricultural irrigation has both advantages and disadvantages. Here are the advantages [2];

- The nutritional composition of wastewater, particularly the existence of nitrogen and phosphorus, offers an enormous possibility for improving agriculture. Utilizing this water as a primary source of these essential nutrients might result in substantial cost savings on supplementary fertilizers. Furthermore, the enhanced soil fertility leads to increased crop yield, adding another dimension of benefit.
- Water scarcity, a pressing issue in many regions, can be mitigated with treated wastewater. This approach ensures the sustainability of usable water, preventing shortages and promoting a more stable water supply.
- Treated wastewater presents an advantage over traditional water sources as it is not dependent on seasonal or environmental factors. This means it is not

affected by seasonal droughts, making it a particularly reliable source for agricultural irrigation, irrespective of the weather or time of the year.

- The use of treated wastewater also contributes to the preservation of good quality surface water bodies. By eliminating the discharge of wastewater into these bodies of water, we can significantly reduce or even eliminate the pollution of these precious resources. Consequently, these limited sources of clean water remain available for use, particularly for drinking purposes.

In addition to these advantages, there are also disadvantages and negative effects, as follows [2].

- A variety of substances present in wastewater could potentially be harmful to the soil and the plants growing in it. These substances, some of which may be toxic, can be present in concentrations that pose a significant threat to environmental health. This is particularly concerning considering the vital role of soil in supporting plant life and biodiversity.
- Pathogenic microorganisms, which are often found in wastewater, can potentially find their way into our food supply through agricultural irrigation. This poses a significant health risk to all living organisms that consume these contaminated foods, underlining the importance of appropriate wastewater treatment before its use in agriculture.
- In certain instances, even wastewater that has undergone treatment can still cause damage to irrigation systems. This can lead to costly repairs and disruptions in agricultural activities, further emphasizing the need for thorough and effective wastewater treatment processes.

Given the many benefits and drawbacks, a determination must be made about the utilization of treated wastewater for agricultural irrigation.

Nevertheless, studies show that the use of treated wastewater for agricultural irrigation is a common practice in numerous countries across the globe. This technique is not only popular but has been in use for a significant amount of time in major cities such as Berlin, London, Milan, and Paris, which have leveraged the potential of wastewater in supporting agriculture. In countries such as Pakistan, this practice is ingrained in their agricultural systems. For instance, a significant 26% of the national vegetable production in Pakistan is attributed to irrigation using treated wastewater. Similarly,

in Hanoi, the capital city of Vietnam, an even larger percentage, 80% of the national vegetable output, is produced through the utilization of wastewater irrigation. This method is also prevalent in African nations like Ghana where approximately 11,500 hectares of agricultural land are irrigated using a combination of treated wastewater and water sourced from streams and rivers. Even though this form of irrigation might not be officially recognized, it is worth noting that the area irrigated in this manner surpasses the officially irrigated agricultural land within the country. In the context of Latin America, Mexico is a prime example where an extensive area of about 260,000 hectares is irrigated using wastewater, primarily raw sewage. In numerous such instances, it is not uncommon for farmers to make use of various forms of wastewater, be it diluted, untreated, or partially treated, for irrigation purposes. This practice, though not ideal, is sometimes the only viable option for farming communities in regions where water scarcity is a significant challenge [9].

2.1.2 Regulatory frameworks for wastewater treatment

Existing standards and regulations on wastewater treatment can be divided into three groups according to their origin: WHO, California and others. Many countries refer to the World Health Organization (WHO) guidelines of 1989. In the United States, each state has its own regulations, but the state of California has been ahead of the curve in wastewater treatment and reuse and has developed its own guidelines. This guide is dated 1992 and consists of 22 criteria. These standards generally consist of numerical limits for bacteriological quality status, water turbidity and suspended solids, which vary according to the various levels of treatment. Other countries, such as Australia and South Africa, have chosen to establish their own set of regulations. The requirements are often determined by the required quantity of wastewater treatment, together with specific thresholds for bacteriological purity, turbidity, and suspended particles [2].

Also, the publication "Wastewater Treatment and Use in Agriculture" from the Food and Agriculture Organization of the United Nations (FAO) is a significant and informative resource that provides recommendations on this topic. The paper provides an overview of the challenges and illustrations of the utilization of treated wastewater and sewage waste in agricultural and aquacultural contexts [10].

Furthermore, in our national legislation, Article 28 on "Use of Treated Wastewater for Irrigation" in the Fifth Section titled "Principles of Discharge of Wastewater" of the Regulation on Water Pollution Control states that "In regions where irrigation water is scarce and of economic value, the use of treated wastewater that meets the irrigation water quality criteria given in the Su Kirliliği Kontrolü Yönetmeliği Teknik Usuller Tebliği is encouraged as irrigation water." [11].

The legal regulations on the use of treated wastewater in irrigation are based on the "Su Kirliliği Kontrolü Yönetmeliği Teknik Usuller Tebliği", which was published in the Official Gazette dated 07.01.1991 and numbered 20748. However, after a few years, the mentioned regulation was repealed and the Seventh Chapter of the “Atıksu Arıtma Tesisleri Teknik Usuller Tebliği", which was published in the Official Gazette dated 20.03.2010 and numbered 27527 and is still in force today, is devoted to the title “Arıtılmış Atıksuların Sulama Suyu Olarak Geri Kullanım Kriterleri”.

2.2 A Comprehensive Examination of Literature About the Site Selection for The Wastewater Treatment Plant

A comprehensive review of the existing literature reveals that both geographic information systems (GIS) and remote sensing methods have become the primary tools in the domain of wastewater treatment plant site selection. These technologies are widely adopted due to their ability to collect, manage, and analyze spatial data effectively, thereby simplifying the complex process of site selection. In addition to GIS and remote sensing, various multi-criteria decision-making methods have also been employed to facilitate the selection process. These methods, which include but are not limited to Analytic Hierarchy Process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and Multi-Attribute Utility Theory (MAUT), are instrumental in weighing different factors and making informed decisions. The following chapter will delve deeper into the literature review, providing a more detailed account of the studies conducted in this field from across the globe. It will also expound on the different methodologies applied in these studies, thereby presenting a comprehensive overview of the current practices in wastewater treatment plant site selection [12].

Mansouri et al. (2013), in their study, aim to prevent environmental pollution with the increase in urban population, improved health and public awareness. Therefore, it has become important to treat wastewater and recover water for further consumption, including agricultural purposes. As the study progresses, they begin to explore the utilization of Fuzzy Hierarchical Analysis (FHA) and GIS. These tools are used in conjunction with the Analytic Hierarchy Process (AHP) for selecting suitable locations for treatment plants. The goal of these strategic choices is to ensure the efficient recovery and reuse of wastewater [13].

In a comprehensive study conducted in 2019, Taghilou et al. selected the Zanjanrood basin, located in the Zanjan province of Iran, as their primary study area. Their primary objective was to identify the most suitable location for the construction of a wastewater treatment plant (WWTP) within the numerous rural complexes that are scattered throughout the basin. While they preferred AHP alone as the analysis method, they ensured that the criteria incorporated a broad range of factors. Furthermore, it seems that Taghilou et al. made a conscious effort to address the gaps found in preceding studies. He meticulously evaluated the criteria that were either overlooked or not well-defined in these previous works [14].

Abdalla et al. (2017) examined the city of Omdurman, one of the largest cities in Sudan in terms of area and population. This city has been experiencing a consistent and steady increase in its population. This escalating growth in its populace is leading to substantial environmental problems and hazards that cannot be overlooked. The city's major pollution issue is the absence of a modern and efficient Wastewater Treatment Plant. The underlying intent was to significantly reduce the city's pollution by addressing the glaring absence of such a necessary facility. To accomplish this, the researchers made use of RS and GIS for the purposes of data collection and mapping. Additionally, AHP was employed as a strategic method for multi-criteria decision making, further aiding in the identification of the best possible site for the WWTP [15].

For similar environmental reasons, Zhao (2015) sets out to mitigate water pollution in his comprehensive study and decided to utilize the AHP in his research. The chosen location for this study is a significant urban center located in the Sichuan province, nestled in the southwestern region of China. This city is of particular importance due to the presence of two major rivers flowing through its heart. The symbiotic relationship between the city and these water bodies is so intertwined that it heightens

the importance of the issue at hand. This geographical detail signifies the city's reliance on these rivers not just for its survival, but also for its growth. Hence, the proposal to establish a sewage treatment plant in the city is not just a necessity, but a pressing requirement to safeguard the health of both the city and its rivers [12].

Shahmoradi et al. (2013), preferred to use Analytic Network Process (ANP) and Fuzzy Logic methods together, which have not been extensively utilized within this field, were chosen over the Analytic Hierarchy Process (AHP), a method that has seen widespread application in the literature concerning the selection of sites for wastewater treatment plants. The task of identifying suitable areas for the construction of essential infrastructure like water and wastewater treatment plants presents a significant environmental challenge within urban planning. By employing two distinct methods together, Shahmoradi et al. sought to overcome this challenge and effectively determine the optimal location for a wastewater treatment plant in the Kahak district of Iran. Their innovative approach underscores the potential benefits of integrating diverse methodologies in addressing complex environmental and infrastructural issues [16].

Anagnostopoulos et al. (2012) deliver a methodology that uses Spatial Fuzzy Analytic Hierarchy Process (SFAHP) in their thorough research. This approach is intended to assist in doing raster-based research related to land use suitableness. This research focused on a specific study area situated in the northeastern region of Greece. Their work aims to promote the greater utilization of treated wastewater in agricultural activities. They suggest this option because it has the potential to greatly enhance the sustainability and efficiency of agricultural practices, particularly in areas where water shortage is a problem [17].

In another study, Fallah et al. (2014) preferred to use the ANN method. Artificial Neural Networks (ANNs), a type of machine learning model inspired by the human brain, have emerged as one of the preferred methods for site selection. This is due to their ability to process vast amounts of data and identify patterns which help in decision-making processes. The use of ANNs in site selection is a testament to how technology has revolutionized this field, making it more efficient and accurate. Furthermore, the use of ANNs in site selection also offers significant time and cost savings. Traditional methods of site selection can be labor-intensive and time-consuming, requiring extensive fieldwork and manual data analysis. In contrast, ANNs

can quickly process and analyze large amounts of data, providing valuable insights in a fraction of the time. This study aims to select the location of the facilities that will treat the wastewater generated by the increase in the daily water demand of humanity, but the inadequacy of natural resources to meet this demand [18].

In their ground-breaking study, Aydi et al. (2016) combined Geographic Information Systems (GIS) with Fuzzy Logic, Analytic Hierarchy Process (AHP), and Weighted Linear Combination (WLC) to explore an area of research that has not yet been conducted on a global scale. Their main motivation behind this innovative research was the absence of a methodological approach for the site selection of an olive oil mill wastewater disposal site in the Sidi Bouzid Region of Tunisia. Aydi et al. states that, within this region, rich in olive oil production, has not yet been the subject of a comprehensive study applying such a strategic method for waste disposal site selection, thus paving the way to undertake their research [19].

In the chapter discussed above, it is evident that there are numerous literature studies that have been undertaken to solve a variety of challenges associated with the selection of suitable sites for wastewater treatment plants. These studies have leveraged the power of Geographic Information Systems (GIS), Remote Sensing (RS), and other methods of Multi-Criteria Decision Making (MCDM) to devise solutions that are both effective and efficient. The methodology and objectives of these studies vary, demonstrating the broad range of approaches and goals in this field. Table A.1 offers a detailed overview of the various studies that were reviewed during the literature review phase. This includes specifics about the methodologies employed in each study, as well as the objectives that guided each piece of research. This comprehensive review of the literature not only provides a robust understanding of the current state of research but also illuminates the path for future studies in this field [20-35].

2.3 Multi-Criteria Decision Making

The cognitive process of decision-making involves the practical application of problem-solving skills to attain a specific goal, and it necessitates careful consideration of a multitude of factors. Logic and reason may serve as a guide for this complex process, or irrational thought processes may have an impact [36]. It might be informed and shaped by implicit or explicit assumptions, which can themselves be influenced by a variety of elements, including, but not limited to, physiological, biological,

cultural, and social aspects. In the context of decision-making, factors such as authority and risk levels can significantly affect the complexity and intricacy of the process. High authority levels might necessitate more careful and detailed analysis, while high-risk situations might call for more cautious and conservative decision-making approaches. In the modern era, advancements in computer technology have provided a powerful tool to tackle complex decision-making problems. Modern computer systems are capable of automatically calculating and predicting answers to complicated problems by utilizing mathematical equations, multidimensional statistics, advanced mathematical models, and economic theories. These technological advancements have revolutionized the decision-making landscape [37].

One such advancement is the development of multi-criteria decision-making (MCDM) models. MCDM is a highly precise method of decision-making that has been regarded as revolutionary in the field. It provides a structured, systematic, and efficient way of analyzing and comparing multiple options to reach a decision. Since the 1950s, scholars have been extensively studying and exploring the mathematical modeling capabilities of MCDM approaches. Their research aims to develop a comprehensive framework that can assist in structuring decision-making problems and establishing a hierarchy of preferences among different alternatives. This rigorous academic research and the development of MCDM models have significantly contributed to the evolution and sophistication of decision-making processes [37].

Over the course of the past few decades, a wide array of multiple criteria decision making (MCDDM) approaches have been diligently developed or significantly enhanced by various authors. These approaches exhibit considerable diversity, each with its unique set of strengths and weaknesses. The key factors distinguishing these approaches from one another include, but are not limited to, the complexity of the algorithms that they employ, the methods that they utilize for weighting criteria, the way they represent preference evaluation criteria, the strategies they adopt for handling data that is unclear or ambiguous, and the type of data aggregation that they use. Each of these factors plays a crucial role in determining the effectiveness and applicability of the MCDDM approach in question, and thus these differences merit careful consideration [38].

Figure 2.3: Steps of MCDM [37].

2.4 Best-Worst Method

The Best-Worst Method, often abbreviated as BWM, is a specific Multiple Criteria Decision Making (MCDM) technique. This method, developed by Dr. Jafar Rezaei in 2015, utilizes two vectors; these are derived from pair-wise comparisons, and their primary function is to determine the weights of various criteria [39].

The process begins with the decision-maker identifying which criteria are the most desirable and which are the least desirable within the approach. Following this initial identification, the process moves on to the next stage. Here, the most desirable criterion is compared with all the other criteria. At the same time, all these other criteria are then compared with the least desirable criterion. To ascertain the weights of each criterion, a non-linear minimax model is employed. This model works by minimizing the largest absolute difference that exists between weight ratios and pair-wise comparisons [40].

One of the unique aspects of the Best Worst Method (BWM) is that it requires fewer pair-wise comparisons than other Multiple Criteria Decision Making (MCDM) approaches. Additionally, it also evaluates the consistency of these pair-wise comparisons. In situations where inconsistencies occur, the BWM suggests numerous solutions for alternative comparisons. BWM is particularly recommended for multi-optimization scenarios, as it offers several different strategies based on the weight sets that have been assigned to the criterion. This feature can be incredibly beneficial for decision-makers, especially during challenging times. This is because multi-optimum solutions can provide greater freedom when it comes to integrating a higher level of knowledge into complex decision-making processes. These processes can include, for example, political decisions, where modeling may not be required. Interval analysis is the technique employed here. In situations where there are no problematic issues present and there is a demand for more knowledge, the decision-maker can choose a single option. The numerous advantages of BWM, including its simplicity and

versatility, have contributed greatly to its increased popularity in recent academic and practical research [40].

According to Razaei, when it comes to implementing the best-worst method, there are several critical steps that must be meticulously followed. Each of these steps plays an integral role in ensuring the method's successful implementation and effectiveness [39].

Step 1. Identifying the necessary criteria.

This first stage involves a thorough evaluation of the criteria $\{C_1, C_2, C_3 \dots, C_n\}$ that are essential for the decision-making process. This process is vital as it sets the foundation for the choices that will be made later. To reach an ideal conclusion, a balanced approach to evaluating the criteria is crucial. It is important to avoid having too few criteria, as this may not provide a comprehensive view of the situation. On the other hand, having too many criteria can lead to confusion and make the decision-making process unnecessarily complicated. The key is to find the right balance so that the most important aspects are taken into consideration.

Step 2. Identifying the best (B) and worst (W) criteria.

The decision-maker must decide the most desirable (B) and least desirable (W) criteria from a comprehensive set of n criteria. This step is crucial as it involves the identification of the most favorable factors, which are the ones that will have the most positive impact on the outcome, and the least favorable factors, which could potentially hinder progress or result in negative consequences. This process might necessitate seeking out professional advice to ensure the most accurate and efficient decision-making. It's important to note that during this initial stage, there's no comparison or evaluation of the different criteria against each other. The goal at this point is purely to identify and understand the fundamental factors that will influence the decision.

Step 3. Involves determining the choice by comparing the best criterion B with all other criteria individually.

During this step, decision-makers assess their preferences on a 9-point binary scale ranging from 1 to 9 for paired comparisons, where 1 signifies that *i* is equally important as *j* and 9 indicates that *i* is much more important than *j*.

$$A_B = (a_{B1}, a_{B2}, \dots, a_{Bn}), \tag{2.1}$$

a_{Bj} represents the favoring of the best criteria *B* over the worst criterion *j*. Logically, it follows that a_{BB} is equal to 1, as this signifies that the best criteria *B* is equally important as itself (a_{BB} = 1).

Step 4. Involves determining the preferred criteria of all other criteria based on the worst criterion.

During this step, DMs assess their choice on a 9-point scale.

$$A_W = (a_{1W}, a_{2W}, \dots, a_{nW})^T, \tag{2.2}$$

The result of comparisons is from others to worst, where a_{jW} represents the preference of criteria *j* over the worst criterion *W*, and obviously a_{WW} is equal to 1.

Step 5. Calculating the optimal weights.

The ideal weight for the criterion is the one that solves the equations $W_B/W_j = a_{Bj}$ and $W_j/W_W = a_{jW}$ for each pair of W_B/W_j and W_j/W_W. To meet these criteria for every *j*, we need to identify a solution with the highest absolute differences $\left| \frac{W_B}{W_j} - a_{Bj} \right|$ and $\left| \frac{W_j}{W_W} - a_{jW} \right|$ for every *j* is minimized. Given the constraints of non-negativity and sum, the following equation comes up:

$$minmax_j^{\square} \left\{ \left| W_B/W_j - a_{Bj} \right| \text{ and } \left| W_j/W_W - a_{jW} \right| \right\},$$

s.t.

$$\sum_j W_j = 1$$

$$W_j \geq 0, \text{ for all } j, \tag{2.3}$$

The model in (2.3) is converted to a linear programming form as shown below:

$$\min \xi$$

s.t.

$$\left| \frac{W_B}{W_j} - a_{Bj} \right| \leq \xi, \qquad \text{for all } j$$

$$\left| \frac{w_j}{w_W} - a_{jW} \right| \leq \xi, \qquad \text{for all } j$$

$$\sum_j W_j = 1$$

$$W_j \geq 0, \text{ for all } j, \tag{2.4}$$

Step 6. Calculating the consistency ratio to assess the consistency of the BWM pairwise comparisons.

The optimal weights $w_1^*, w_2^*, \ldots, w_n^*$ and ξ * are determined by solving the linear programming problem in (2.4). This equation plays a vital role in the solution process as it provides the necessary mathematical framework for the optimization. Following the computation of these weights, a subsequent step in the process involves the utilization of the formula provided below. This specific formula is employed with the primary objective of verifying the consistency of the Best Worst Method (BWM) pairwise comparisons. The verification of consistency within these comparisons is a crucial aspect of the overall process, ensuring the reliability and validity of the outcomes achieved.

$$\text{Consistency Ratio} = \xi^* \,/\, \text{Consistency Index} \tag{2.5}$$

For the calculation of the consistency index, the values in Table 2.1 provided by Rezaei are used [39]. The consistency ratio is computed to assess the consistency of the comparisons. If $a_{Bj}\, x\, a_{jW} = a_{BW}$ for every j, then the comparisons are totally consistent. Full consistency may not always be attainable. This consistency ratio is a value ranging from 0 to 1. numbers around 0 indicate higher consistency, whereas numbers near 1 indicate lower consistency. Strive to maintain a consistency ratio below 0.25 for more reliable outcomes.

Table 2.1: Consistency Index (CI) Table.

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency Index (max ξ)	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

The scale that has been utilized for the assignment of numerical values is presented in Table 2.2, along with their corresponding interpretations. It is important to note that the scale, which ranges from 1 to 9, bears a striking resemblance to the scale established by Saaty in his seminal work on the subject matter.

Table 2.2: Likert scale with definitions used in BWM.

Importance Level	**Definition**	**Explanation**
1	Equal importance	Both have the same effect
3	Moderate importance of one over another	Strongly favor one activity over another
5	Essential or strong importance	Strongly favor one activity over another
7	Very strong importance	An activity is strongly favoured, and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest order
2,4,6,8	Intermediate values	Compromise

3. METHODOLOGY

Currently, Remote Sensing (RS) and Geographic Information System (GIS) are not just important branches of science, but indispensable methods for collecting, processing, and organizing data. They are routinely and extensively applied in a myriad of research that requires geolocation. GIS is a highly sophisticated, computerized system that zeroes in on geographic matters. It makes use of a wealth of geospatial data for comprehensive analysis, encompassing vital location information such as longitude, latitude, and altitude. The scope and function of a GIS system are comprehensive. It oversees and manages the entire process, starting from data collection, moving on to data processing, and finally, data display. Given the dynamic nature of scientific research, there's a constant need for more sophisticated and current methods of data handling. In response to this, numerous innovative approaches are being rapidly developed to cater to the demands of various scientific endeavors. One such approach that has proven to be highly effective is the Multi-criteria Analysis (MCA). MCA offers an objective and scientific way for decision-makers to make systematic choices. It does this by incorporating a multitude of elements derived from extensive geographical data. One common application of MCA is in the optimization of facility location. This is a multi-criteria decision-making process that is frequently leveraged by both private and governmental organizations. The goal is to make an informed decision about the best possible location for their operational facilities, by considering a variety of factors and data [41].

In this direction, the primary focus of this study is the utilization of multi-criteria decision-making methods during the evaluation phase of selecting a location for Wastewater Treatment Plants.

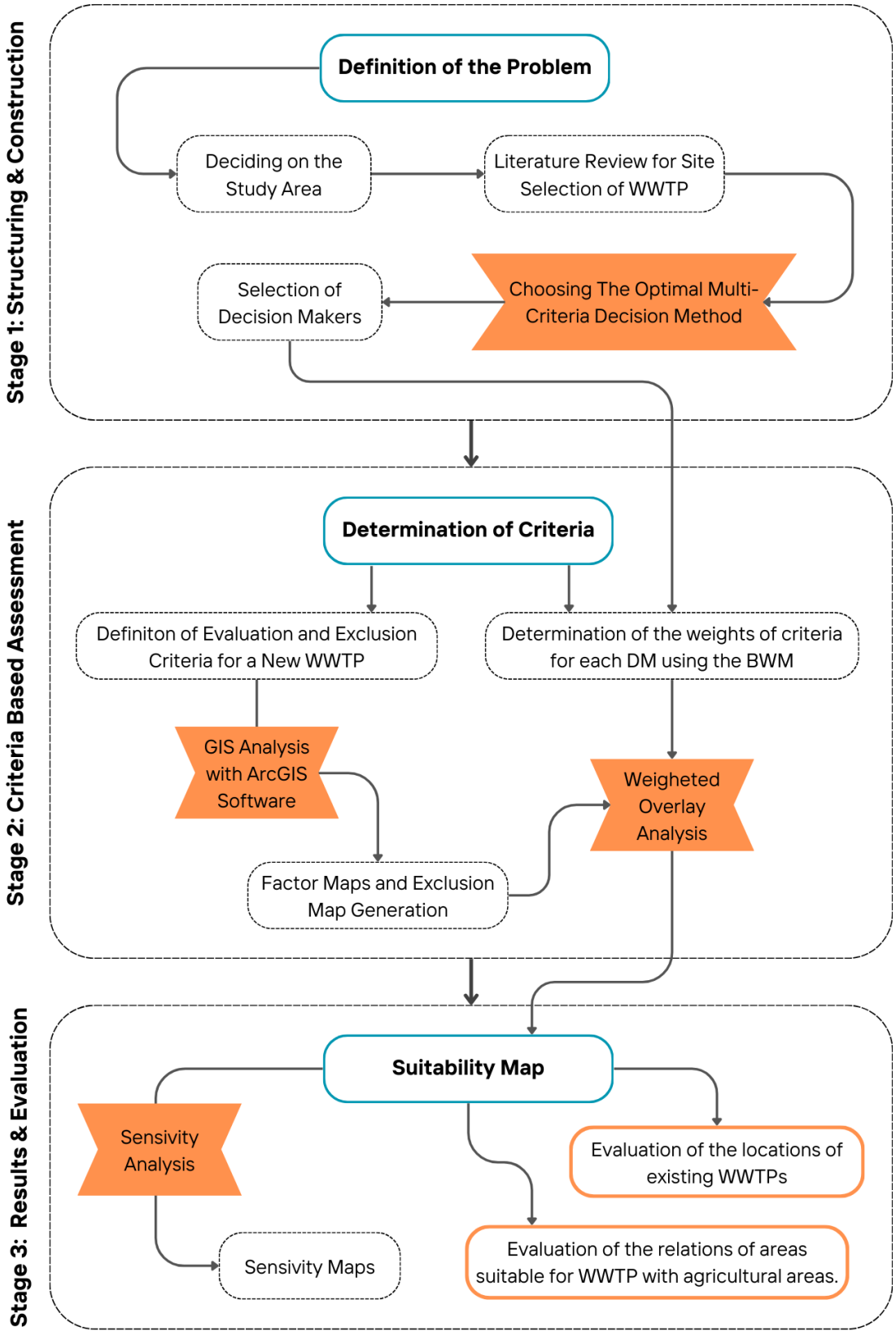

Figure 3.1: Flowchart of the Methodology.

The study's structure consists of three distinct stages. The initial phase involves structuring and constructing the process. This aspect starts by clearly identifying and stating the problem that needs attention. Once the problem has been defined, the subsequent course of action involves determining the field of study. This decision is based on answering a critical question: which field of study is most necessary and relevant to adequately address and resolve the identified problem? After selecting the appropriate field of study, the process proceeds to an exhaustive review of existing literature. This review specifically targets studies that have previously addressed the same or similar problem and have proposed various solutions. The examination of existing literature is a crucial step in shaping the direction and progression of the research process. This is because it enables a diverse range of perspectives and methodologies to guide and inform the current study. In this way, the process not only benefits from previous work done in the area but is also able to avoid potential pitfalls and build upon established knowledge. This thorough and detailed approach in the initial phase of the study ensures a robust and comprehensive foundation for the subsequent stages.

Upon completion of the literature review, the study proceeds with the selection of the most optimal multi-criteria decision-making method. During this significant phase, various methods previously utilized and examined in the existing literature are considered. However, the objective of this study is not merely to adopt a pre-existing method. Instead, our goal is to explore uncharted territory by employing a method that has not yet undergone extensive testing or adoption in the existing literature. Thus, the Best Worst Method is chosen as a novel and promising methodology for this study, serving as an alternative to the Analytic Hierarchy Process (AHP), which is a more traditional method.

Following the selection of the decision-making method, the next crucial phase involves identifying the decision-makers. These individuals are key contributors whose expert opinions will be solicited in subsequent stages of the study. The selection of these experts is of paramount importance, as they play a significant role in shaping the study's outcomes. The selection process is careful and deliberate, with a strong emphasis placed on identifying experts from various disciplines. This diverse panel of decision-makers is critical as it ensures a range of perspectives are considered in the study, thereby increasing the robustness and comprehensiveness of the results. The

multi-disciplinary approach aims to equip the experts with the necessary subject matter expertise and enable them to offer unique and valuable insights into the topic from various perspectives. Therefore, this careful selection of decision-makers aims to significantly enhance the quality and breadth of the study's findings.

In the second phase of this study, the methodology involves a rigorous, criteria-based assessment process. This process is multifaceted and entails the identification of various criteria and subsequent analysis. The criteria for evaluation in this study are meticulously determined, considering the specific requirements and characteristics of the study area. This process also considers the criteria utilized in existing studies within the literature review, ensuring a thorough and comprehensive approach.

The subsequent steps systematically categorize and differentiate these criteria. They are divided into two distinct groups: those that will be evaluated and classified to assess the suitability of the area, and those that must be excluded and never selected due to various reasons. This categorization process is crucial, as it ensures that all relevant factors are considered in the decision-making process while inappropriate or irrelevant criteria are carefully omitted. Following the categorization, geospatial representations of the criteria, in the form of factor maps and excluded maps, are produced. These maps provide a visual and spatial overview of the criteria, helping to understand and evaluate the study area. It means that the process involves the careful identification, analysis, and categorization of various criteria, culminating in the production of detailed factor and exclusion maps. This meticulous approach ensures that all relevant factors are considered, and inappropriate criteria are omitted, resulting in a robust and thorough evaluation.

Simultaneously with the activities, the decision-makers who were identified in the prior stage were tasked with the responsibility of assigning weights to the criteria. These criteria were established within the context of the application requirements of the Best Worst Method. This panel of decision-makers comprised a total of eight individuals, including five academicians and three practicing engineers who have extensive field experience. These experts were entrusted with the task of applying weights to the criteria and making selections for the best and worst criteria.

Following this weighting process, the next step involved the utilization of the Geographic Information System (GIS) capabilities of the ArcGIS Pro software. The factor and exclusion maps, which had been previously prepared, were subjected to a Weighted Overlay analysis within the same GIS software environment. The decision-makers assigned the weights accordingly. As a result of this rigorous analytical process, a suitability map was generated. This map is composed of a total of five classes that span the spectrum from the most suitable areas to the most unsuitable areas. This comprehensive map is a visual representation of the suitability of various locations, offering a valuable tool in the decision-making process. Thus, through a systematic and detailed process involving the active participation of expert decision-makers and the application of sophisticated GIS software, a comprehensive and informative suitability map was produced.

The final phase of the study is dedicated to generating results and conducting comprehensive evaluations. This stage is characterized by the execution of meticulous sensitivity analyses. The objective of these sensitivity analyses is to assess the impact of modifying the weights assigned to each criterion on the overall suitability map. This is achieved by systematically adjusting the weights of the criteria individually and subsequently observing the resultant alterations in the suitability map. As a final step in this analytical process, a detailed sensitivity map is constructed, visually representing the influence of each criterion's weight on the suitability of different areas.

Simultaneously, the results obtained during this phase are used to critically evaluate the existing locations of the wastewater treatment plants within the study area. This evaluation is conducted against the backdrop of the classifications presented in the suitability map, thereby offering a comprehensive understanding of how well the current locations align with the optimal areas as determined by the study. Furthermore, this final stage of the study involves a thorough examination of the relationship between areas deemed suitable for wastewater treatment plants (WWTP) and the agricultural regions within the area. This evaluation is directly grounded in the initial problem statement, which served as the foundation for the entire study. By investigating this correlation, the study aims to provide a nuanced understanding of the spatial dynamics at play and contribute valuable insights into the strategic placement of wastewater treatment facilities in relation to agricultural zones.

In summary, the final phase of the study is a rigorous and in-depth process that involves performing sensitivity analysis, evaluating existing wastewater treatment plant locations, and investigating the relationship between suitable areas for WWTP and agricultural zones. This results in a comprehensive understanding of the methodological approach and its implications, ultimately enhancing the study's overall validity and applicability.

3.1 Determination of Criteria

The initial phase in determining the criteria to be used in this study involves considering the existing standards and regulations for wastewater treatment plants sitting in the region where the site selection will be made. This is an essential step as it ensures compliance with established guidelines and statutory requirements, thereby providing a solid and compliant foundation for the study. Following this, a comprehensive literature review must be conducted. This review should seek to understand which criteria have been used in previous studies and the reasons why these criteria were determined by individuals. Given the global nature of the topic, it is necessary to examine numerous literature studies that have chosen different areas of the world as their study area and used different methods. This broad scope ensures a diverse range of perspectives and methodologies, which significantly enhances the robustness and comprehensiveness of the study.

It is worth noting that the sitting of wastewater treatment plants has been a widely discussed topic in the literature. This is particularly because it deals with an issue that aims to reduce environmental risks, thus attracting considerable attention and discussion. In alignment with this, a significant amount of literature on this subject exists, offering a wealth of knowledge and insights.

Within the scope of this study, and as mentioned in the section detailing the literature studies examined in the previous sections, the criteria that 23 recent studies have evaluated in wastewater treatment plant site selection have been tabulated. This systematic collation of criteria from various studies provides a comprehensive overview of the criteria considered in wastewater treatment plant site selection and offers valuable insights into the methodologies and approaches adopted by other researchers. Following this comprehensive review and compilation process, the indispensable criteria are determined. This process involves examining the frequency

of use of the criteria in these studies. The geographical, economic, and environmental aspects of the Konya Closed Basin are then considered, and a total of 10 criteria are emphasized in Table 3.1. Of these, seven are marked for evaluation, while three are excluded. This rigorous and meticulous approach ensures a well-rounded, comprehensive, and relevant set of criteria for the study, thereby enhancing its validity and applicability.

Table 3.1: Criteria ID's and Criteria Definitions

Criteria ID	Criteria	Criteria ID	Criteria
C1	Slope	C6	Distance from Settlements
C2	Elevation	C7	Soil Type
C3	Distance from Road Network	C8	Distance from Faults
C4	Land Use / Land Cover	C9	Distance from Airstrip
C5	Distance from Water Bodies	C10	Distance from Protected Areas

In a comprehensive analysis as depicted in Table 3.1, we have carefully evaluated a total of 10 criteria. These were selected based on their frequent utilization in the literature associated with wastewater treatment plant site selection. Following a systematic review of literature and subsequent meticulous analysis, a final decision was reached regarding the inclusion of these criteria.

For further elucidation, Table 3.2 provides a detailed breakdown of the frequency with which these criteria have been employed in a total of 23 studies. It also outlines the various sources that have utilized each criterion. A noteworthy observation from this analysis is the predominance of the slope criterion, which has been incorporated in a significant majority of the literature. Specifically, it was incorporated in 20 out of the 23 studies examined, indicating its importance and relevance in the process of site

selection for wastewater treatment plants. Another criterion of considerable relevance is the land use criterion, which was featured in 19 studies. Additionally, the criteria pertaining to distance to road network and settlements were included in 18 studies. This highlights the importance of these factors in the site selection process, further emphasizing the need for comprehensive and diverse criteria in our study.

Interestingly, despite being evaluated in only one study, the criterion of distance to airstrips emerged as critical when considering the specific characteristics of our study area. Though it may not have been heavily emphasized in the literature, this criterion's role in our study will be further elaborated upon in the subsequent sections. This highlights the importance of tailoring the selection of criteria to the specific needs and characteristics of the study area, rather than solely relying on the frequency of their usage in the literature. Consequently, this approach ensures that our study's evaluation process is both robust and context-specific, thereby enhancing its validity and applicability.

Table 3.2: Criteria that used in reviewed literature.

Ref. No	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	■		■	■	■	■	■	■		■
2	■	■	■	■		■	■			
3	■	■	■	■	■	■	■			
4	■	■	■	■	■	■				
5			■		■	■		■		
6	■		■	■	■	■		■		
7	■		■	■		■				
8	■		■	■	■	■	■			■
9		■	■	■		■				
10	■			■	■	■				■

Table 3.2 (continued): Criteria that used in reviewed literature.

Ref. No	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
23										
25										
TOTAL	20	10	18	19	15	18	10	4	1	4

3.1.1 Slope

In site selection for wastewater treatment plants, the consideration of slope is of paramount importance due to its economic and environmental implications. When a wastewater treatment facility is erected on a steep terrain, it can escalate the costs associated with excavation and backfilling operations. Moreover, a steep slope can intensify the flow of leachate, a liquid waste product, towards surface water and

groundwater resources. This could potentially endanger these vital water resources, posing serious environmental concerns [13].

A review of existing literature reveals variation in the recommended slope for the construction of wastewater treatment plants. This variation is based on the specific conditions of the area under consideration. Some studies suggest that a slope between 0-2% is most appropriate, considering the total slope of the area. Meanwhile, other studies have found that locations with up to 25% slope can be deemed suitable. In the context of our current study, we specifically evaluated the slope of the Konya Closed Basin. Upon thorough evaluation, it was determined that areas with a slope between 0-7% are most suitable for the construction of wastewater treatment plants. This determination was made after careful consideration of the unique characteristics and needs of the Konya Closed Basin. The process highlights the importance of a nuanced and context-specific approach when considering factors such as slope in site selection for wastewater treatment facilities.

3.1.2 Elevation

The factor of elevation plays a pivotal role when selecting a suitable site for the establishment of Wastewater Treatment Plants and the design of associated sewerage networks, including those with water transmission lines. An optimally designed wastewater treatment plant follows a configuration where wastewater is transported through a channel via gravity. This necessitates the selection of a site for the WWTP that is situated at the lowest possible elevation within the area under consideration, ensuring that it is lower than the surrounding residential areas. This is crucial as it aids in the efficient flow and management of wastewater within the plant. Moreover, areas with high elevations should be deliberately avoided due to the potential increase in costs associated with the construction and operation of the WWTP. Such sites may necessitate additional costs related to excavation, backfilling, and other preparatory and maintenance operations. If required, it would be more cost-effective to invest in a site located at a lower elevation, even if it involves a higher initial expenditure [15].

Considering the Konya Closed Basin, the region of interest in our study, the elevation varies significantly. The lowest point in the basin is at an elevation of 891 meters, while the highest point reaches up to 3404 meters. Considering these values, the most suitable areas for the establishment of a WWTP, in terms of elevation criteria, are

determined to lie within the elevation range of 891 to 1124 meters. This specific range of elevation was identified based on a thorough analysis of the topographical characteristics of the Konya Closed Basin and considering the operational requirements and efficiencies of a wastewater treatment plant.

3.1.3 Distance from road network

The criterion of proximity to the road network is a critical element that merits careful consideration in the construction of a wastewater treatment plant. This is primarily due to the variability in construction and maintenance costs associated with the location of the plant in relation to the road network.

The physical proximity of wastewater treatment plants to the road network can have multiple implications. On one hand, such proximity can have a detrimental impact on the landscape, climate, and public health. This is due to potential factors such as noise pollution, increased traffic, and the potential for accidental spills or leaks that might contaminate the surrounding environment. On the other hand, positioning a wastewater treatment plant far from the road network can result in significant losses in terms of both time and economic resources. This is primarily due to increased transportation costs, including those related to the transportation of materials and personnel, and the higher cost of constructing access roads to the plant [33].

Therefore, it becomes vitally important to strike a balance between these two extremes. This balance is achieved by carefully evaluating the potential benefits and downsides, and then determining an optimum distance to the road network that minimizes negative impacts while maximizing operational efficiency and cost-effectiveness. It needs to provide a balance between minimizing the negative impacts of proximity to the road network while ensuring that transportation costs do not become prohibitive.

Consequently, areas that are less than 300 meters from the road network and those that are more than 4000 meters away are deemed as the most unsuitable locations for constructing a wastewater treatment plant. This is primarily due to the inability to establish the balance. In the case of areas less than 300 meters from the road network, the negative impacts on landscape, climate and public health may become too significant. Conversely, in areas more than 4000 meters away from the road network, the increased transportation costs and time may outweigh the benefits of reduced environmental impacts. This comprehensive and thoughtful approach to the distance

to the road network criterion ensures the selection of the most suitable site for the construction of a wastewater treatment plant.

3.1.4 Land use / land cover

Land use and cover, which can include various categories such as industrial, agricultural, residential, and natural areas, significantly shape the terrestrial landscape. In many instances, land use is primarily dictated by the type of vegetation found in the area. However, human activities and interventions can also play a major role in determining land use. The categorization of land as sensitive or less sensitive is a fundamental aspect of sustainable development and economic growth. This classification assists in ensuring that areas of environmental significance receive appropriate protection. Residential areas, agricultural lands, and natural spaces such as parks and forests are typically classified as sensitive lands. These areas often host an array of biodiversity and contribute substantially to environmental health, making their protection critical. On the other hand, industrial and commercial lands are generally considered less sensitive due to their primary association with human activities rather than natural ecosystems [13].

The careful management and appropriate designation of these lands are crucial for achieving sustainable living standards and preserving environmental integrity. Mismanagement or inappropriate use of sensitive land can lead to detrimental environmental impacts, which can have far-reaching consequences for both human and ecological health.

Within the scope of this study, a comprehensive review of the relevant literature was conducted to evaluate land use areas considered suitable and unsuitable for the site selection of Wastewater Treatment Plants (WWTP). The analysis revealed that land use areas such as pastures, barren rocky areas, and areas with sparse vegetation or saline conditions are deemed suitable for WWTP site selection. These areas are often less susceptible to environmental degradation due to their existing conditions, making them ideal candidates for industrial activities such as the establishment of WWTPs. On the other hand, the study identified agricultural areas, marshlands, airports, urban textures, water bodies, and areas with significant vegetation as unsuitable for WWTP site selection. These areas are typically characterized by their high environmental sensitivity, and their conversion for industrial use could lead to severe environmental

degradation. Therefore, these areas must be protected and excluded from consideration for wastewater treatment plant establishment to ensure environmental sustainability.

3.1.5 Distance from water bodies

In the realm of wastewater management, the strategic positioning of wastewater treatment facilities and discharge areas is of paramount importance. Notably, these areas should be deliberately situated at a considerable distance from various water bodies such as rivers, lakes, streams, ponds, or swamps. This stipulation is grounded in the objective of preserving the integrity of these water resources and protecting the diverse aquatic life they sustain. The reason behind this approach is the potential risk of dirty water leakage from wastewater treatment plants. Such leakage, if occurred near surface water bodies, can result in the pollution of these crucial resources, thereby threatening both the quality of water and the survival of aquatic organisms. Hence, it is of utmost importance to ensure that these facilities are located at a significant distance from any surface water bodies [28].

This requirement is not merely a recommendation but is firmly embedded in the legislation of numerous countries. Many jurisdictions prohibit the discharge of wastewater into any form of surface water, be it rivers, lakes, or streams. This prohibition reflects the global commitment to preserving our water resources and maintaining the health of our ecosystems [13].

A review of existing literature on wastewater treatment plant site selection reveals a consensus on the need for a substantial buffer between these facilities and water bodies. On average, the literature suggests a minimum distance of 300 meters. However, this figure varies depending on the specific context and characteristics of the study area. In the specific context of our study area, the Konya Closed Basin, we have determined that the most suitable areas for wastewater treatment facilities are those located at least 2000 meters away from any surface water bodies. Conversely, the areas within a 500-meter radius from the water bodies are deemed the most unsuitable. This decision is a result of a meticulous examination of the unique geographical, environmental, and legislative factors pertinent to the Konya Closed Basin. Through this approach, we aim to ensure the effective and sustainable management of wastewater while safeguarding our valuable water resources and the ecosystems they support.

3.1.6 Distance from settlements

In the selection and establishment of wastewater treatment plants, one of the most critical considerations is their proximity to residential areas. This concern arises from the potentially harmful environmental conditions and unpleasant odors that these plants can generate. It's well-documented that such factors can pose threats to human health, making it pivotal for these facilities to be located at a safe distance from populated zones. However, determining this 'safe distance' requires a careful and thorough cost-benefit analysis. This analysis should consider various factors, including potential health risks for the local population, environmental impact, and the operational efficiency and cost-effectiveness of the wastewater treatment plant itself. Based on the findings of such an analysis, it is advised to consider a buffer zone of at least 1000 meters from residential areas when locating wastewater treatment plants [15].

In the context of our current study, after careful consideration of factors such as cost-benefit and the specific characteristics of our study area, it was determined that the most appropriate buffer zone for wastewater treatment plants lies between 1000 and 4000 meters from residential areas. This decision was reached with the understanding that a buffer zone of less than 500 meters would be too close, posing potential health and environmental risks. Conversely, a buffer zone of more than 10 kilometers would likely be impractical in terms of cost and would undermine the operational efficiency of the wastewater treatment plant. Furthermore, it's worth noting that our study area is characterized by a significant number of rural areas, in addition to urban zones. This adds another layer of complexity to the decision-making process, as these rural areas may be more sensitive to the impacts of wastewater treatment plants. As such, our determination of the appropriate buffer zone has taken this unique aspect of our study area into account.

3.1.7 Soil type

The type of soil at a potential site is a crucial factor to evaluate when selecting a location for a wastewater treatment plant. The soil's properties can significantly influence the facility's operational efficiency and environmental impact. Specifically, the soil type impacts the seepage rate of any wastewater that might unintentionally leak from the facility, as well as the soil's capacity to absorb the properties of these

pollutants. The characteristics of soil that are particularly relevant in this context include the texture of the soil's surface, the ratio of sand and gravel within it, and its salinity, alkalinity, and solubility ratios. These characteristics collectively determine the soil's permeability and are a critical factor in assessing the potential environmental impact of a wastewater treatment plant. Soils with a medium to heavy surface texture are generally beneficial for these facilities because they provide a stable foundation and minimize the risk of structural instability or subsidence. A higher gravel content can also be advantageous, as it can enhance the soil's natural filtration capabilities. Moreover, soils with high salinity levels can help to neutralize some of the chemical components in the wastewater, thereby reducing its potential environmental impact. Conversely, soils with low alkalinity are preferable because high alkalinity can lead to alkaline wastewater, which can have harmful environmental effects if it leaks into the surrounding soil or water bodies [15].

When considering the specific characteristics of the study area, it was necessary to comprehensively evaluate all different soil types of present. This involved a detailed comparison of the properties of these soils with those of similar soil types discussed in the literature. The findings from this comparison served as the basis for determining the suitability of each soil type for a wastewater treatment plant. Areas with high salinity levels and non-swampy conditions were found to be preferable for site selection. These areas can effectively neutralize wastewater and mitigate the risk of significant environmental damage in the event of a leak. Additionally, most of the study area was found to have a moderate degree of settleability due to the characteristics of its soil type. This implies that the soil in these areas is relatively stable and unlikely to cause structural issues for a wastewater treatment plant.

3.1.8 Distance from faults

The issue of seismic safety is of paramount importance when considering the siting of Wastewater Treatment Plants (WWTPs). Considering potential seismic hazards, it is crucial to formulate precautionary measures to ensure the integrity of these facilities. One such measure is the establishment of buffer zones along both sides of existing fault lines within the area of interest. This measure is not solely determined by the soil structure and lithology of the area; rather, it also accounts for unforeseen events that could potentially result in the leakage of contaminated water from the WWTP in the

event of a seismic hazard. Consequently, fault lines should be considered a critical criterion in the process of WWTP site selection [17].

In the context of the Konya Closed Basin, the area of focus for this study, it is crucial to consider the geological conditions. While the area does not present a high risk of intense seismic activity, it remains essential to evaluate this criterion and accordingly exclude areas that are unsuitable due to their proximity to fault lines. This approach aligns with the findings from existing literature, where it is common practice to establish a buffer zone of 500 meters or 1,000 meters around fault lines. However, this distance can be increased up to 2,000 meters in regions characterized by a higher risk of earthquakes. For the purposes of this study, based on the specific geological conditions of the Konya Closed Basin, a buffer zone of 1,000 meters is deemed sufficient. This represents a balanced and cautious approach, considering both the specific characteristics of the area and the potential risks associated with seismic activity. This comprehensive and detailed approach ensures a robust and safe strategy for the siting of Wastewater Treatment Plants.

3.1.9 Distance from airstrips

Wastewater treatment plants, with their associated sumps and ponds, have the potential to attract a variety of bird species. This attraction, while it may be of interest to bird watchers and nature enthusiasts, poses a significant risk to the operations of airports and airstrips. Birds are known to be a hazard to aircraft, and their presence in the vicinity of airstrips can be particularly dangerous. Hence, it becomes crucial to factor in the distance to airstrips when choosing locations for the establishment of WWTPs. This is a significant consideration, especially in regions where the presence of birds is particularly abundant or where protected bird species are known to inhabit [35].

In the context of our study area, the Konya Closed Basin, this consideration takes on an even greater significance. The Konya Closed Basin is recognized as an area of high importance for nature conservation by the World Wildlife Fund (WWF) in Turkey. Its rich biodiversity, particularly in terms of bird species, makes it a critical habitat that needs to be protected. The basin is home to 14 Important Bird Areas including Samsam Lake, Kozanlı Gökgöl, Kulu Lake, Ereğli Reeds, Karapınar Plain, Eşmekaya Reeds, Suğla Lake, Beyşehir Lake, Hotamış Reeds, Bolluk Lake, Tersakan Lake, Salt Lake, Desert Lake, and Uyuz Lake. The presence of these important bird areas within the

basin underscores the need for careful and considerate planning when selecting sites for WWTPs [42].

The selection of a site for WWTP needs to consider not just the immediate needs of wastewater treatment but also the broader environmental and ecological implications of such facilities. A WWTP located too close to an airstrip, or an Important Bird Area could have detrimental effects on bird populations and pose risks to aviation safety and because of that at least 2000 m buffer should be considered. Hence, the selection process must involve a careful evaluation of the potential sites, their proximity to airstrips and important bird habitats, and the likely impact of the plant on local bird populations.

3.1.10 Distance from protected areas

The consideration of proximity to protected areas is another pivotal criterion that significantly influences the decision-making process for the siting of WWTP. This criterion has been examined and incorporated in several studies within the existing literature, underscoring its importance in the process of WWTP location selection [19].

The Konya Closed Basin, which is the primary focus of our study, is a region particularly rich in protected areas. This region is home to a multitude of protected areas of varying types and sizes, including Special Environmental Protection Areas (SEPA) (referred to as "Özel Çevre Koruma" or ÖÇK in Turkish), natural parks, natural monuments all of which are located within the confines of the basin borders. Among these protected areas, Tuz Lake and its surroundings, as well as the Ihlara Valley in Aksaray, are notable for being classified as large SEPA areas. Furthermore, the region surrounding Beyşehir Lake has dual significance as it is both a delineated wetland buffer zone and is also included within the boundaries of a large national park [5,6].

When considering the siting of WWTP, it is of paramount importance to maintain a respectful distance from such as 1000 m these protected areas. This is to ensure that the integrity and ecological balance of these areas are not compromised due to the potential environmental impact of the WWTP. Thus, the careful consideration of proximity to protected areas as a criterion in the site selection for WWTP is not just an important aspect, but a prerequisite in the decision-making process.

3.2 Data Preparation

The stage of data preparation is a pivotal point within this study. This phase encompasses the procurement of the most current data from a variety of sources prior to conducting necessary analyses. Furthermore, it includes the correct and precise classification and presentation of this data, if required, before the implementation of Geographic Information System (GIS) analyses. As elucidated in the preceding section, it is also of utmost importance to determine which of the identified criteria will be incorporated into the analysis as factors, and which criteria will be wholly excluded from consideration.

This process of data preparation begins with the careful sourcing of data from various reputable and reliable sources. The data obtained must be the most current and up to date to ensure the accuracy and relevance of the subsequent analyses. This data is then meticulously classified and presented in a clear and comprehensible manner, to facilitate its effective utilization during GIS analysis. However, it should not be forgotten that it is an open-source work. Following this, a critical decision-making process is instigated to determine which of the previously identified criteria will be included in the analysis as factors. This process requires a careful evaluation of each criterion's relevance and significance to the study, as well as its potential impact on the study's outcomes. Concurrently, decisions must also be made regarding which criteria will be completely excluded from the analysis. These decisions must be made judiciously, considering the potential implications of including or excluding each criterion.

The process of data preparation is an integral part of the study, requiring thoroughness, precision, and critical decision-making skills. It lays the foundation for the subsequent analyses and greatly influences the study's outcomes. Therefore, it is essential that this process is conducted with the utmost care and attention to detail.

Table 3.3: Detailed Information of the Data Source.

Criteria ID	Data	Source
C1	Slope	USGS EarthExplorer (25m Resoluiton DEM, GeoTIFF
C2	Elevation	USGS EarthExplorer (25m Resoluiton DEM) GeoTIFF
C3	Primary and Secondary Road Network	Open Street Map Turkey Roads (vector), 2023
C4	Detailed Land Cover	Copernicus Urban Atlas Land Cover (vector), 2018
C5	Water Bodies and Waterways	Open Street Map (vector), 2023
C6	Urban Fabric	Copernicus Urban Atlas Land Cover (vector), 2018
C7	Soil	FAO (Food and Agriculture Organization) Digital Soil Map of the World (vector), 1977
C8	Fault Lines	ArcGIS Living Atlas (feature service from Global Earthquake Model Foundation (GEM)), 2021
C9	Airstrip Locations	Open Street Map (vector), 2023
C10	Protected Areas	Doğa Koruma ve Milli Parklar Genel Müdürlüğü (vector), 2020
C11	LocationS of Existed WWTP	Digitized from Konya Havzası Stratejik Çevre Değerlendirme Raporu, 2023

From the information provided in the Table 3.3, it is evident that all the necessary data required for site selection, in relation to all the identified criteria, have been sourced from the most updated and reliable open sources. This thorough data procurement process ensures that the site selection process is based on the most recent and relevant data, thereby enhancing the accuracy and reliability of the selection process.

Firstly, the most recent land use map that encompasses the area of our study was initially acquired in our analysis. Upon visual inspection of the map Figure 3.2, it is evident that our study area comprises 32 distinct land use zones, each associated with a unique land use type. A large portion of the area is dedicated to agricultural pursuits, notably areas sown with various crops and irrigated fields. This is a significant consideration for our study as these agricultural areas are likely to have specific requirements and constraints that must be considered in our analysis. Another noticeable feature of the landscape is the extensive presence of salt pans and marshlands surrounding Salt Lake. This unique geographical feature adds another layer of complexity to our study as these areas may pose certain environmental and logistical challenges. In conclusion, the land use map obtained from the Urban Atlas offers a detailed and up-to-date visual representation of the various land use zones within our study area. This will serve as an invaluable resource in our analysis, aiding us in understanding the complexities of the landscape, informing our decision-making process, and ultimately helping us to identify the most suitable locations for the proposed Wastewater Treatment Plants.

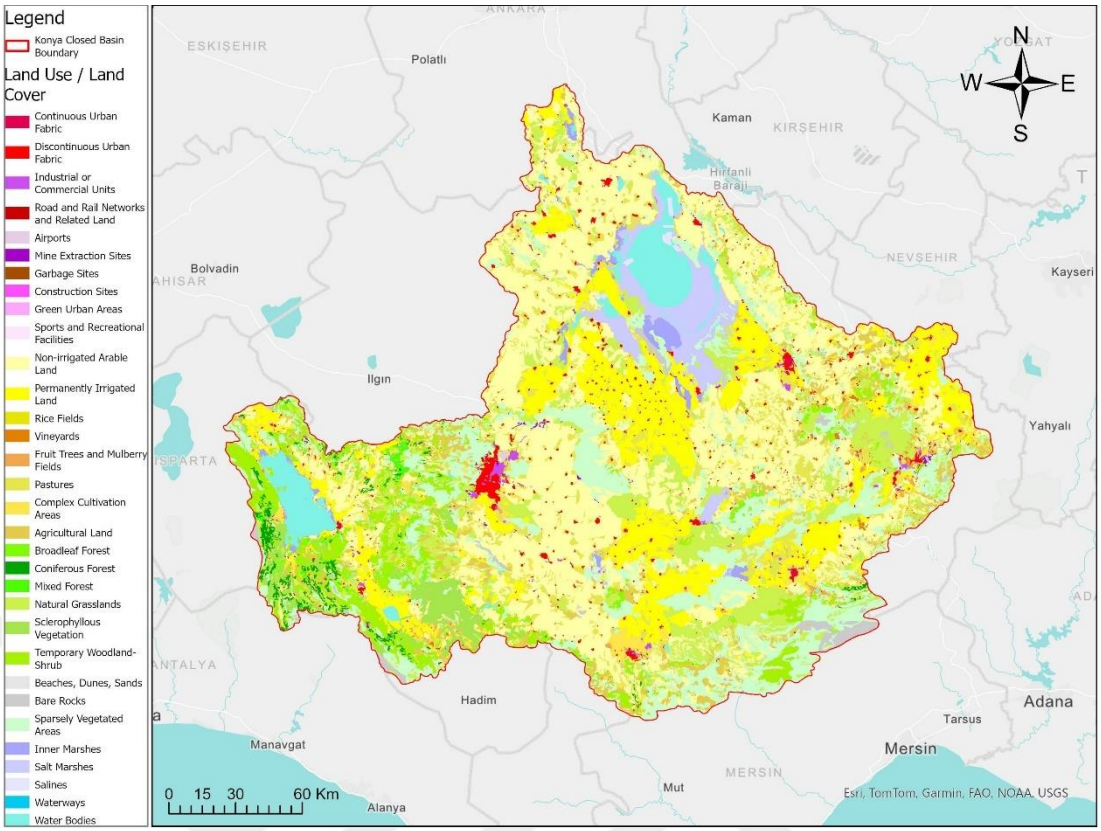

Figure 3.2: Land Use Map.

In parallel, this study necessitated the collection of settlement data. This was achieved by merging layers of continuous urban fabric and discontinuous urban fabric present in the land use data in Figure 3.3 (a). The term 'continuous urban fabric' refers to highly developed urban centers within the boundary of the basin, while 'discontinuous urban fabric' denotes rural settlements with a less dense population. Remarkably, within the basin, there are close to 800 different settlements, both urban and rural. Based on the total area calculation conducted using ArcGIS Pro, it was determined that the settlement area spans approximately 85,000 hectares.

Furthermore, to facilitate this research, data pertaining to the road network and water bodies was procured as open-source resources via OpenStreetMap. This data, updated till 2023, was subsequently visualized and incorporated into the analysis. It's noteworthy that while the road network data is considerably extensive, only primary, and secondary roads were considered for this study in Figure 3.3 (b). Among the data on water bodies and waterways in Figure 3.3 (c), certain characteristic features of the study area stand out, including Tuz Lake and Beyşehir Lake, which are also significant lakes in Turkey.

Additionally, to construct a map of soil types in Figure 3.3 (d), global scale data from 1977, published by the Food and Agriculture Organization (FAO), was used. This data is available in an open-source format as a shapefile. According to FAO's soil type classification, the study area comprises 10 different soil types. As depicted in the figure, most of the area is characterized by Calcic Xerosols type soil. Additionally, in the southern part of the area, Lithosols type soil is observed. This detailed and comprehensive approach to data collection and analysis ensures a robust and thorough understanding of the study area, thereby enhancing the validity and applicability of the study's findings.

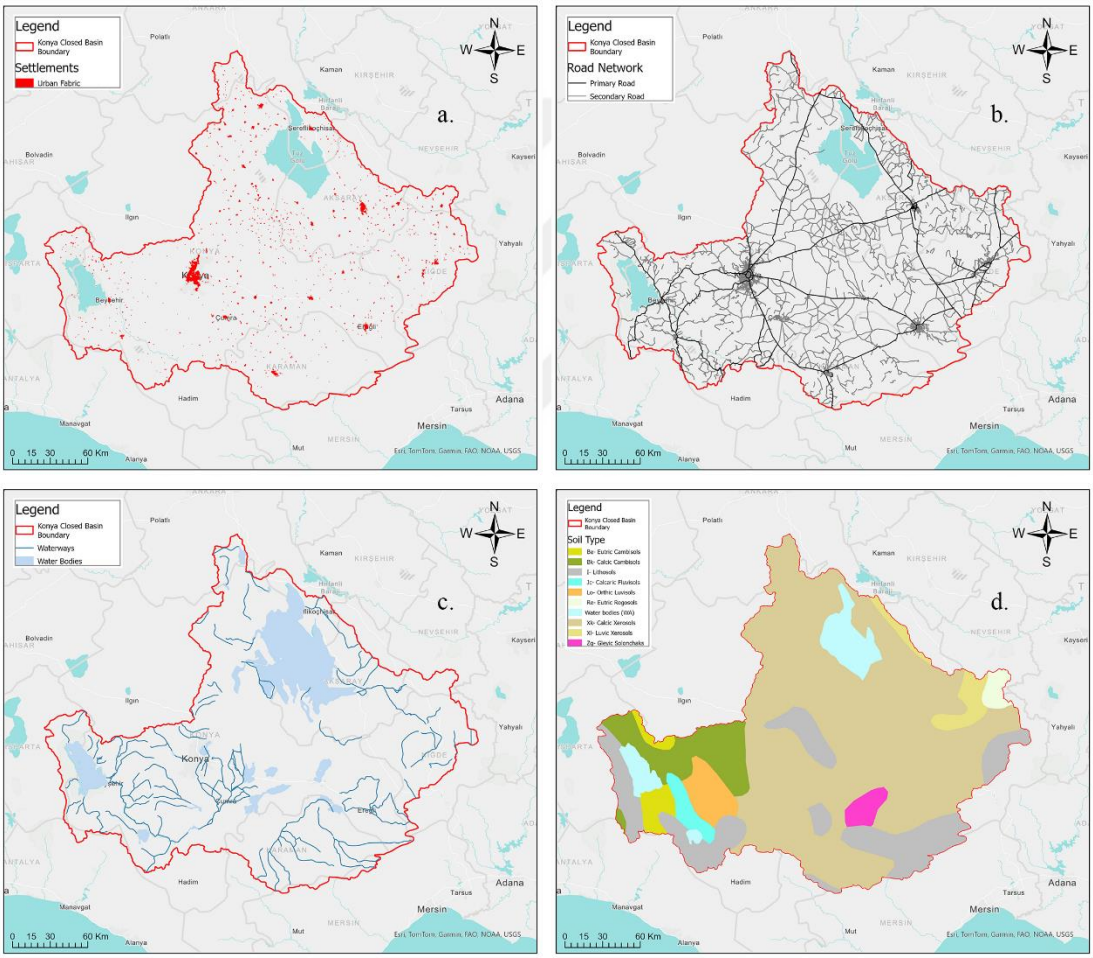

Figure 3.3: Settlements Map (a), Road Network Map (b), Waterways & Water Bodies Map (c), Soil Types Map (d).

The methodology used for the generation and analysis of slope and elevation criteria involved the use of a common data set. Specifically, we utilized the Digital Elevation Model (DEM) data which was extracted from the United States Geological Survey (USGS) Earth Explorer. The chosen data had a resolution of 25 meters, which was

ample for our study's requirements. This data set was downloaded in the GeoTIFF format to ensure compatibility and ease of use with our study area. Once downloaded, the DEM data was imported into the ArcGIS Pro software, a cutting-edge GIS application that is renowned for its advanced capabilities in spatial data analysis. Within the ArcGIS Pro environment, the DEM data was subjected to a 'clipping' process to confine the data to the boundaries of our study area. This ensured that our subsequent analysis was focused solely on the area of interest.

One of the unique aspects of DEM data is that it inherently provides information about elevation. However, for our study, we required data not only on elevation but also on slope. To generate the slope data, we utilized the Slope analysis tool available within the ArcGIS Pro software. This tool allowed us to produce a raster data set representing the slope of our study area in Figure 3.4 (a).

To enhance the visual clarity and comprehensibility of our data, we decided to alter the symbol and value ranges of the slope data. This modification was based on our understanding of the area and the specific requirements of our study.

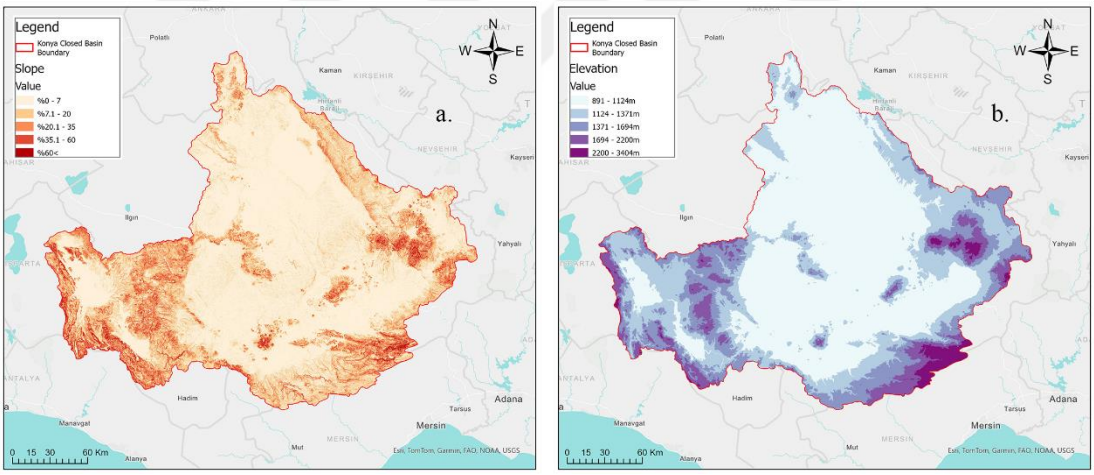

Figure 3.4: Slope Map (a), Elevation Map (b).

Concurrently, we used the elevation data in Figure 3.4 (b) to produce a shaded relief map**.** This type of map in Figure 3.5 provides a three-dimensional representation of the terrain, with areas of higher elevation appearing lighter and areas of lower elevation appearing darker. To facilitate interpretation, we applied appropriate coloration to the shaded relief map. Upon inspection of the resultant shaded relief map, one geographical feature was particularly noteworthy. This was Mount Hasan, a prominent volcanic mountain located in the eastern part of our study area. As one of the most

significant volcanic mountains in Turkey, Mount Hasan is an important landmark that merits attention in our study.

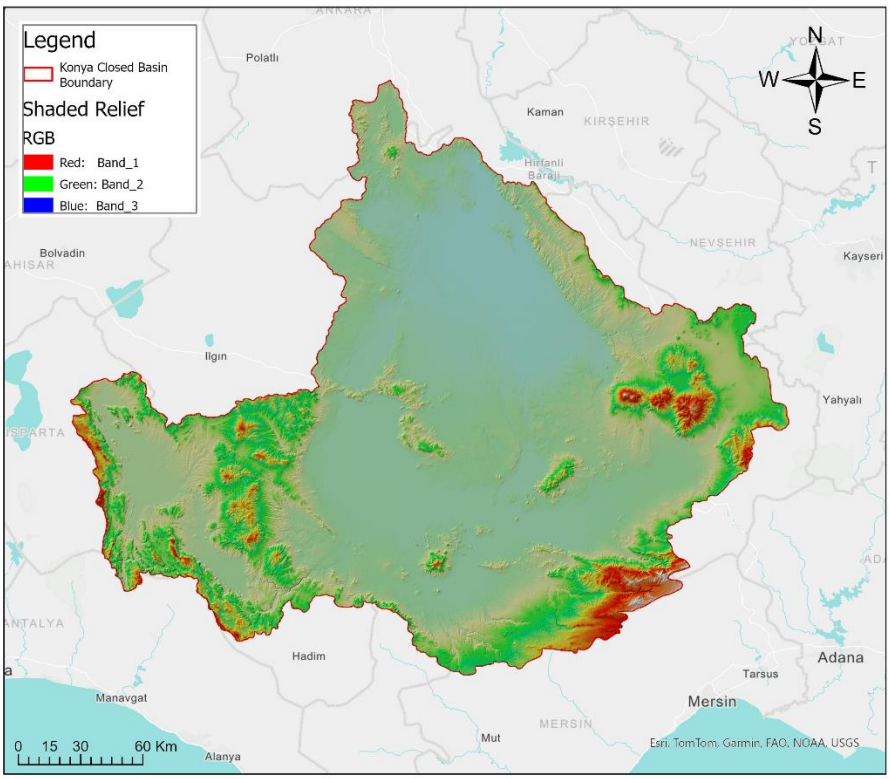

Figure 3.5: Shaded Relief of the Study Area.

Another critical factor that needs to be taken into consideration when deciding on the location for a wastewater treatment plant is the presence of fault lines in the area. To gain accurate and up-to-date information regarding fault lines, we utilized data from the Living Atlas of the World platform, provided by ArcGIS as a direct feature service in ArcGIS Pro in Figure 3.6 (a). According to the data description in the Living Atlas, the fault line information is sourced from the Global Earthquake Model Foundation (GEM), and the data used is the most recent, from 2021.

In addition, it is essential to consider the locations of airstrips in the area. To that end, airstrip locations were incorporated into the land use data downloaded from the open street map. This dataset was chosen due to its recency. Within the area of consideration, there are four airstrips, with the one closest to Konya province being the largest in Figure 3.6 (b).

Furthermore, it is also crucial to consider protected areas within the vicinity. The data on protected areas is vector data obtained from the Directorate of Nature Conservation

and National Parks and is taken from 2020. This data reveals that a significant portion of the area is covered by Special Protection Areas, such as around Tuz Lake and Ihlara Valley, along with nature parks and Ramsar sites in Figure 3.6 (c).

Lastly, to avoid selecting an area where a wastewater treatment plant already exists and to evaluate the suitability of existing locations based on the results, it was necessary to identify the locations of existing wastewater treatment plants in Figure 3.6 (d). To accomplish this, we referred to the Konya Basin Strategic Environmental Assessment Report for 2023 to determine the locations of existing wastewater treatment plants on the map. These locations were then digitized using ArcGIS Pro and incorporated into the study. Our research indicates that there are a total of 24 wastewater treatment plants within the study area.

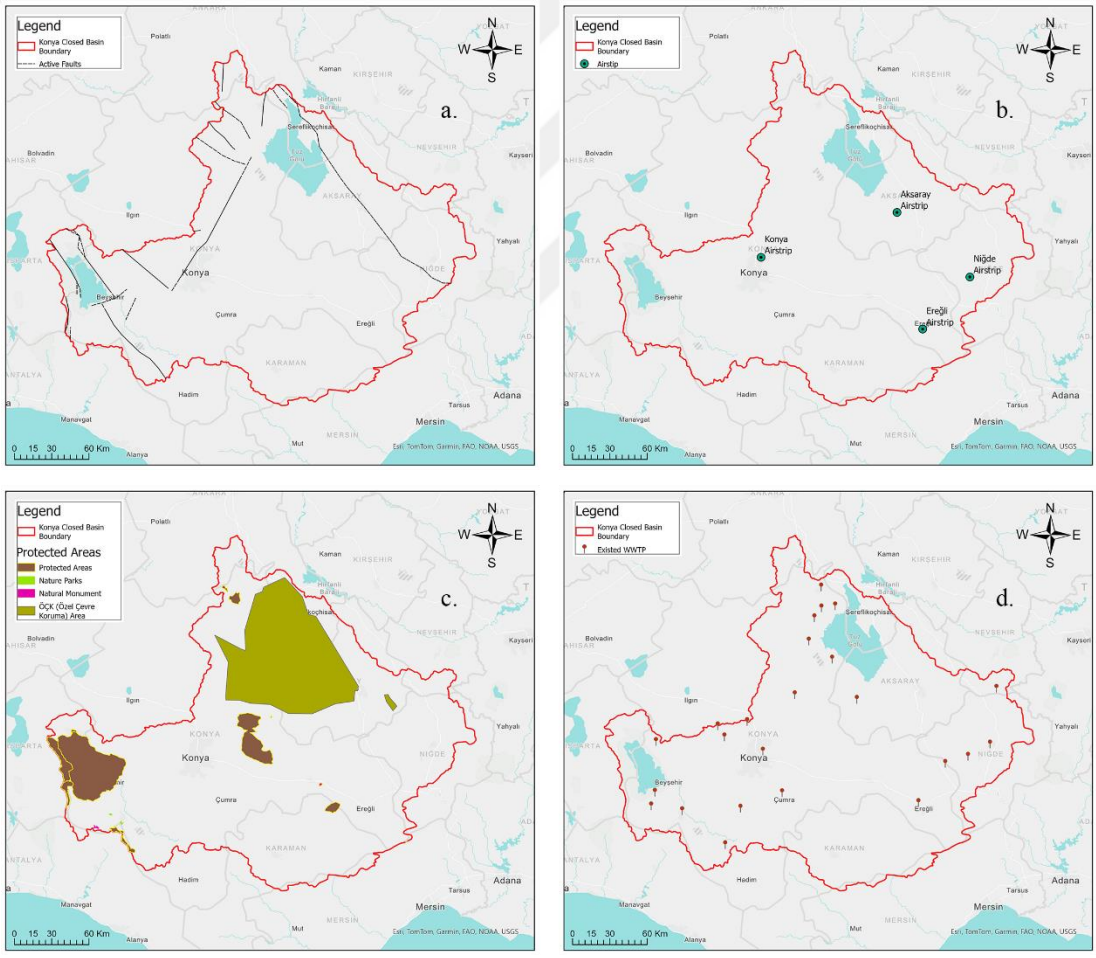

Figure 3.6: Faults Map (a), Location of Airtstrips (b), Protected Areas (c), Existed WWTP Locations (d).

4. GENERATION OF SUITABILITY ANALYSIS

The Generation of Suitability Analysis is a critical stage in the planning and decision-making process. This analysis involves identifying the most suitable areas or locations based on specific criteria or conditions. The process involves the use of Geographic Information System (GIS) tools to analyze spatial data and determine suitability.

Up until this, several fundamental stages have been undertaken, all of which have set the stage for the execution of the suitability analysis. These stages encompass the determination of the relevant criteria, the meticulous preparation of the data, and the selection of the most optimal multi-criteria decision-making method to be utilised.

Moreover, in this section, we will provide an in-depth look at the creation of the exclusion map. This stage is crucial as it involves deciding which among the required criteria will be excluded from the suitability analysis. The process of preparing factor maps using GIS software, in accordance with predetermined optimal ranges, will also be detailed. As seen in the Table 4.1, it is explained which of the existing criteria will be included as factors and which will be excluded. Next, the factor maps will be prepared using the ArcGIS Pro software and a quintile classification system. This step in the process will enable us to determine suitable areas by conducting a weighted overlay analysis.

The daunting task of calculating the weights of the criteria a requirement for the weighted overlay analysis will be thoroughly detailed in this section. We will also give emphasis to the workflows related to the application of the Best-Worst Method. Lastly, we will provide a comprehensive detailing of the sensitivity analyses and their results. This analysis involves changing the weights assigned to the criteria and evaluating the subsequent effect on the suitability map. This final stage allows for an understanding of how alterations in the assigned weights can influence the overall suitability map, thus providing valuable insights for decision-making.

Table 4.1: Criterias and their purpose of use.

Criteria ID	Criteria	Purpose
C1	Slope	Factor
C2	Elevation	Factor
C3	Distance from Road Network	Factor
C4	Land Use / Land Cover	Factor & Exclusion
C5	Distance from Water Bodies	Factor & Exclusion
C6	Distance from Settlements	Factor & Exclusion
C7	Soil Type	Factor
C8	Distance from Faults	Exclusion
C9	Distance from Airstrip	Exclusion
C10	Distance from Protected Areas	Exclusion
C11	Existed WWTP	Exclusion

4.1 Exclusion Map Generation

In the section titled "Determination of Criteria," it is outlined that out of the ten total criteria identified, three were immediately incorporated into the study with the explicit purpose of being excluded from the suitability analysis. As it seen in Table 4.2, these criteria are the active fault lines, designated with the identifiers C8, C9, C10, and their associated 1000-meter buffer zones, airports along with their surrounding 2000-meter buffer zones, and protected areas accompanied by their peripheries extending to 1000

meters. Beyond these, areas that have been identified as hosting existing Wastewater Treatment Plants (WWTPs), represented as polygons, were also purposefully excluded from the suitability analysis (C11).

In addition to these criteria, it is important to note that all settlement areas and water bodies have been deemed as factors in the analysis. However, it is critical to highlight that the internal regions of these areas are treated as exclude criteria, removing them from consideration in the suitability analysis. This decision ensures the integrity of the analysis by preventing potential conflicts with existing infrastructure and environmental considerations.

However, the areas that areunsuitable for site selection extend beyond the ones previously mentioned. Within the first criterion, C1, which pertains to the slope, areas featuring a slope of 60% and above are considered unsitable. A review of the literature reveals that for many studies, even slopes above 40% are considered unsuitable for site selection. However, a thorough and tailored evaluation of the specific circumstances of the Konya Closed Basin led to the decision to set the limit at 60% [21, 28, 29, 35]. Similarly, for the second criterion, C2, which focuses on elevation, any location at or above an elevation of 2200 meters is deemed unsuitable. It should be noted that the highest elevation point within the area under study is 3404 meters. In C3, which examines the distance from the road network, has its own exclusions. Any area within a range of 0-300 meters from the road network is considered too close and thus unsuitable. Furthermore, areas beyond 4000 meters from the road network are also excluded due to the negative implications for transportation costs that this distance would entail [14, 23, 25, 28, 35]. For the fourth criterion, C4, which relates to Land Use/Land Cover (LULC), there are several categories of land that are deemed unsuitable. These include urban fabric areas, road and railway networks and related lands, waste disposal sites, green urban areas, recreational areas, agricultural lands, beach areas, sand and dunes, inland and salt marsh areas, as well as water bodies [15, 32]. In C5, which assesses the distance from water bodies, excludes not only the water bodies themselves but also a 500-meter buffer zone [14, 16, 28, 35]. For the sixth criterion, C6, which considers the distance from settlements, all settlements are excluded, as mentioned in both C4 and the criteria that should be directly excluded. Additionally, the first 500-meter buffer area around the settlements and areas beyond 10,000 meters were identified as unsuitable for site selection due to the negative impact

on transportation costs, analogous to the logic applied in C3 [14, 15, 28]**.** Finally, according to the seventh criterion, C7, which pertains to soil type, the areas featuring 'Calcaric Fluvisols' type soil were deemed unsuitable for site selection. This decision was based on the outcomes of various studies examined in the literature, which evaluated the permeability rate and salinity rate of the soils among the nine soil types found within the study area [13,15, 19, 29, 35].

Table 4.2: Exclusion Criteria.

Criteria ID	Criteria	Exclusion
C1	Slope	%60< (Unsuitable)
C2	Elevation	2200m< (Unsuitable)
C3	Distance from Road Network	0-300m & 4000m< (Unsuitable)
C4	Land Use / Land Cover	Road Networks Related Lands, Waste Disposal Sites, Green Urban Areas, Recreational Areas, Agricultural Lands, Beachs, Sand & Dunes, Inland & Salt Marsh Areas (Unsuitable)
C5	Distance from Water Bodies	Direct & 0-500m buffer (Unsuitable)
C6	Distance from Settlements	Direct & 0-500m & 10000m< (Unsuitable)
C7	Soil Type	Calcaric Fluvisols (Unsuitable)
C8	Distance from Faults	Direct & 1000 m buffer
C9	Distance from Airstrip	Direct & 2000 m buffer
C10	Distance from Protected Areas	Direct & 1000 m buffer
C11	Existed WWTP	Direct

During the process of suitability analysis, the Reclassify tool, which is a geoprocessing capability offered by ArcGIS Pro, is an essential component. Its primary function is to reclassify the values inscribed in a raster or effect changes in the values contained within each individual cell. This capability is pivotal when managing the complex data sets required for our criteria-specific analysis [49]. Once the data, tailored to our specific criteria, has been collected, the next stage of the process commences. This involves identifying areas to exclude based on the vector data. To facilitate this, the Buffer tool is employed. This tool functions by creating an offset buffer zone around the feature it is applied to. The result is an output that visually represents the areas to be set aside [50]. Following the Buffer tool application, the features exported are then merged into a single entity using the Merge tool. This amalgamation is a crucial step, ensuring that the diverse features are consolidated into a coherent, unified whole [51]. Subsequently, this merged feature is converted to a raster format. A series of reclassification processes are then completed, resulting in the formation of a distinct layer. This layer, indicative of the areas to be excluded from the suitability analysis which can be seen in Figure 4.1, is then removed from the overall data set. This action is undertaken prior to the execution of the weighted overlay analysis for suitability.

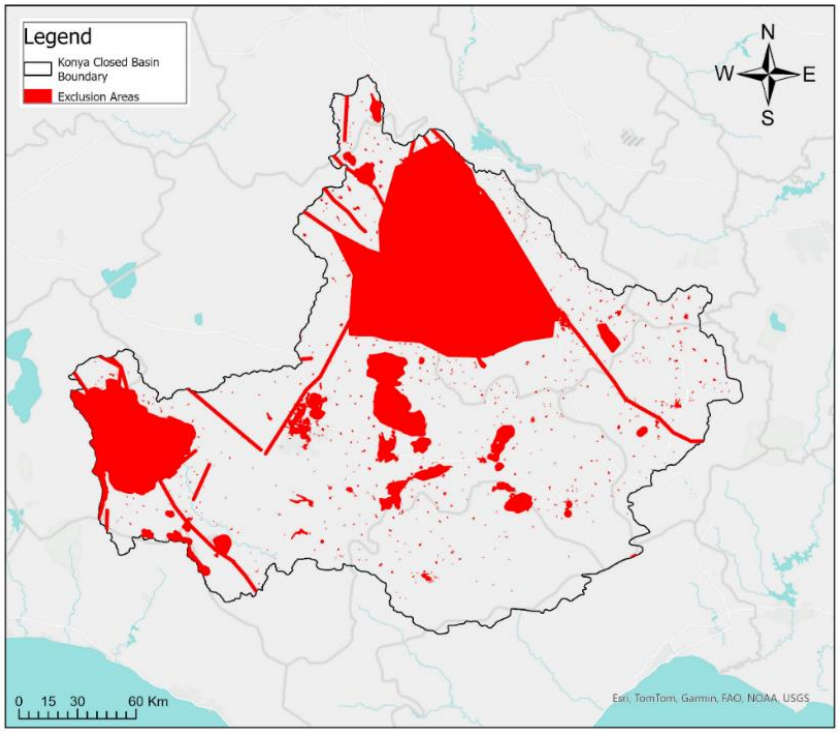

Figure 4.1: Exclusion Map.

4.2 Factor Maps Generation

Upon identifying the areas that are deemed unsuitable and hence, excluded from site selection, we proceed to the next crucial step. This step involves categorizing the criteria based on a five-tier classification system. The five tiers are as follows: unsuitable, very low suitability, low suitability, moderate suitability, and high suitability. This quintile classification system provides a comprehensive, layered analysis, facilitating a nuanced understanding of the suitability of different areas. In accordance with this classification system, we must determine the respective ranges for the seven key criteria, which are slope, elevation, distance from road network, land use / land cover, distance from water bodies, distance from settlements, and soil type. The determination of these ranges is carried out meticulously, considering the findings from an extensive review of relevant literature, as well as considering all necessary legal requirements.

As elaborated upon in the 'Determination of Criteria' section, the following tables demonstrate the interval values for each tier in the quintile classification. These values have been derived through a careful process of analysis and deliberation. Corresponding to these interval values, maps have been prepared using the sophisticated GIS software, ArcGIS Pro. These maps are prepared to visually represent the data, providing a clear and intuitive understanding of the suitability analysis, and are essential for conducting a Weighted Overlay analysis with views of decision makers. Visual aids serve as a crucial component in our research, as they transform complex datasets into easily interpretable illustrations that showcase the geographic distribution of various suitability levels across the regions of interest. The use of these maps enhances our understanding and interpretation of the data, thereby aiding in making informed and accurate decisions. This is an essential step in ensuring the reliability and robustness of our suitability analysis, which is of utmost importance in the context of this study. In essence, this process of determining the areas to be excluded and subsequently classifying the criteria based on a quintile system is a rigorous and comprehensive approach. It ensures a high level of accuracy in our suitability analysis, thereby contributing to the reliability and robustness of our findings and decisions.

Table 4.3: Slope Reclassification.

Criteria	Optimal Interval	Reclassified Value	Suitability Degree
Slope	%60<	1	Unsuitable
	%35.1 -60	2	Very Low Suitable
	%20.1 -35	3	Low Suitable
	%7.1 -20	4	Moderate Suitable
	%0 -7	5	High Suitable

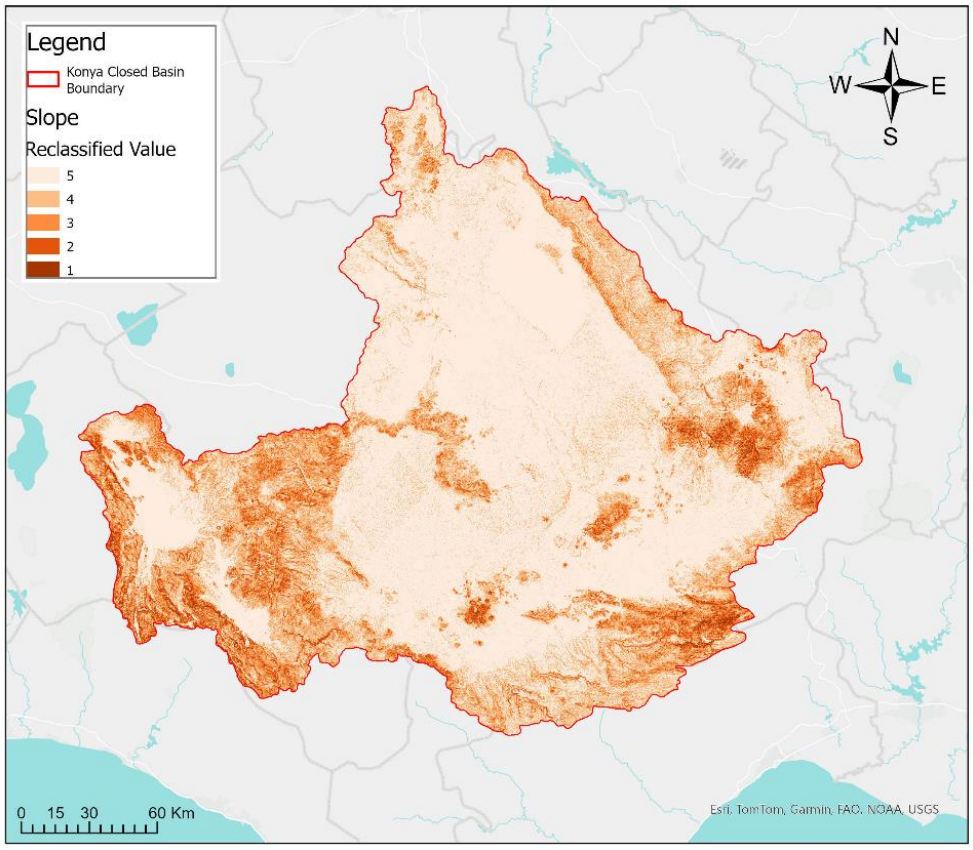

Figure 4.2: Slope Reclassification Map.

Table 4.4: Elevation Reclassification.

Criteria	Optimal Interval	Reclassified Value	Suitability Degree
Elevation	2200m - 3404m	1	Unsuitable
	1694m - 2200m	2	Very Low Suitable
	1371m - 1694m	3	Low Suitable
	1124m - 1371m	4	Moderate Suitable
	891m - 1124m	5	High Suitable

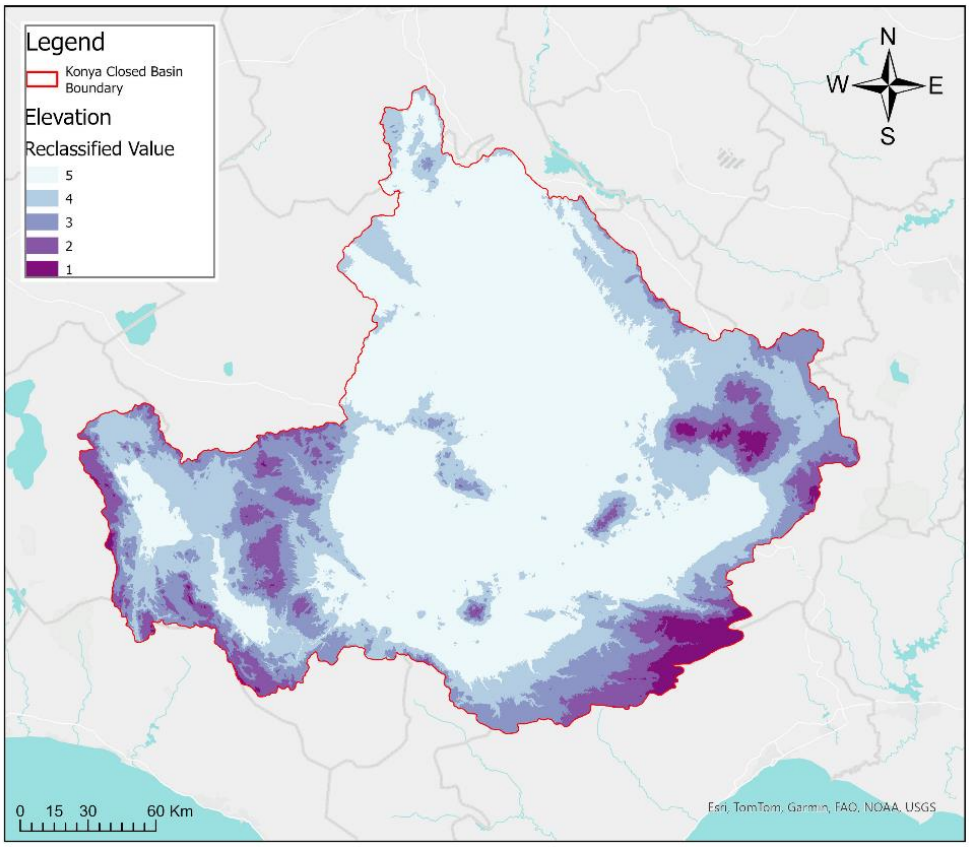

Figure 4.3: Elevation Reclassification Map.

Table 4.5: Distance from Road Network Reclassification.

Criteria	Optimal Interval	Reclassified Value	Suitability Degree
Distance from Road Network	0-300m & 4000m<	1	Unsuitable
	3000m - 4000m	2	Very Low Suitable
	2000m - 3000m	3	Low Suitable
	1500m - 2000m	4	Moderate Suitable
	300m - 1500m	5	High Suitable

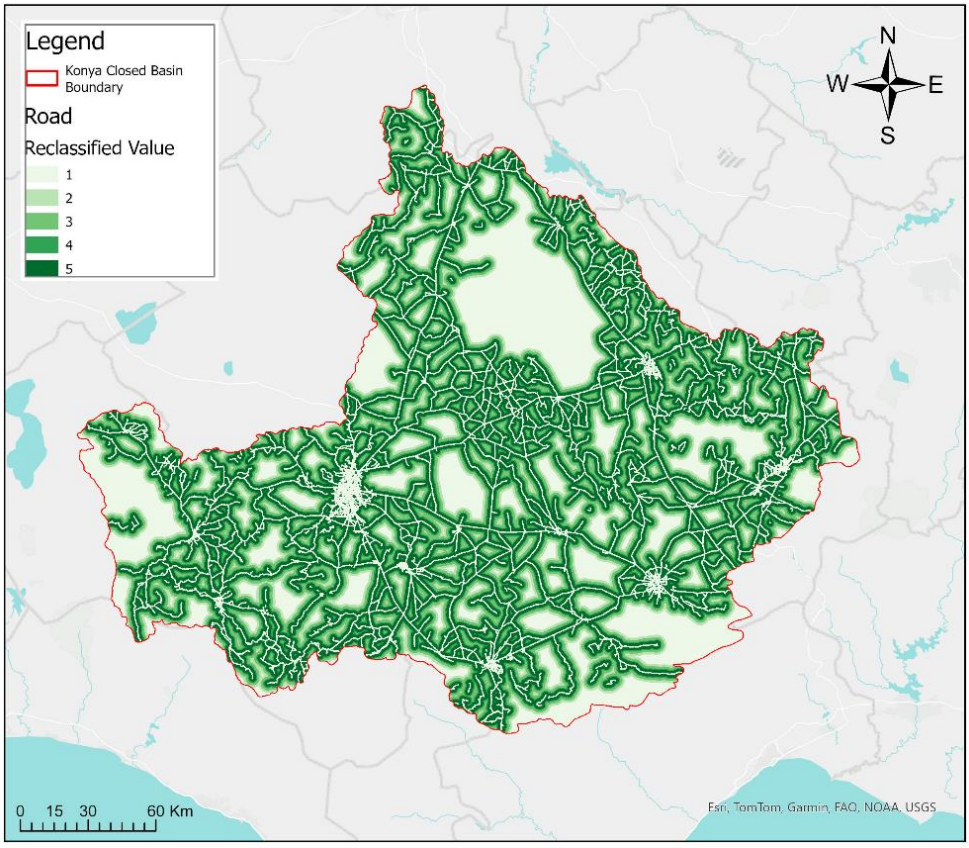

Figure 4.4: Distance from Road Network Reclassification Map.

Table 4.6: Land Use / Land Cover Reclassification.

Criteria	Optimal Interval	Reclassified Value	Suitability Degree
Land Use / Land Cover	Road Networks Related Lands, Waste Disposal Sites, Green Urban, Recreational Areas, Agricultural Lands, Beachs, Sand & Dunes, Inland & Salt Marsh Areas	1	Unsuitable
	Permanently Irrigated Land, Rice Paddies, Vineyards, Fruit Trees & Berry Plants, Agricultural Croplands	2	Very Low Suitable
	Industrial Or Commercial Units, Mining Sites, Construction Sites, Broadleaved Forest, Coniferous Forest, Mixed Forest, Sclerophyllous Vegetation, Temporary Woodland-Shrub	3	Low Suitable

Table 4.6 (continued): Land Use / Land Cover Reclassification.

Criteria	Optimal Interval	Reclassified Value	Suitability Degree
Land Use / Land Cover	Non-Irrigated Arable Land, Natural Grasslands	4	Moderate Suitable
	Pastures, Empty Rocky Areas, Sparsely Vegetated Areas, Saline Areas	5	High Suitable

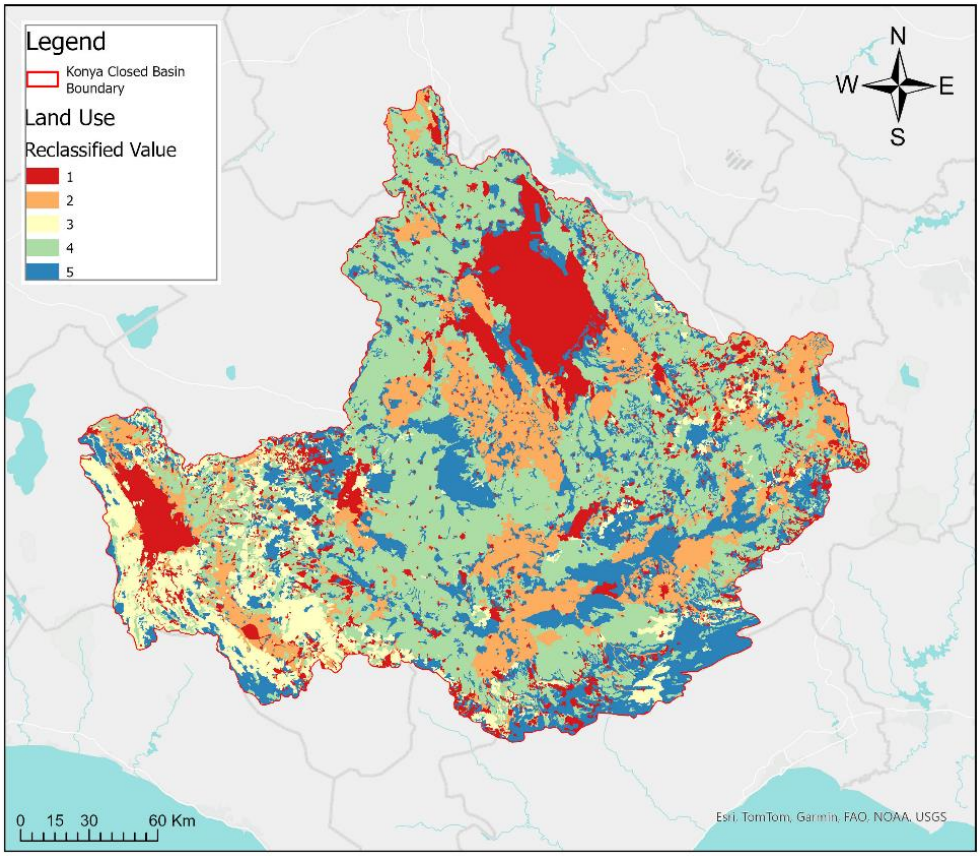

Figure 4.5: Land Use / Land Cover Reclassification Map.

Table 4.7: Distance from Water Bodies Reclassification.

Criteria	Optimal Interval	Reclassified Value	Suitability Degree
Distance from Water Bodies	0 - 500m	1	Unsuitable
	500m - 1000m	2	Very Low Suitable
	1000m - 1500m	3	Low Suitable
	1500m - 2000m	4	Moderate Suitable
	>2000m	5	High Suitable

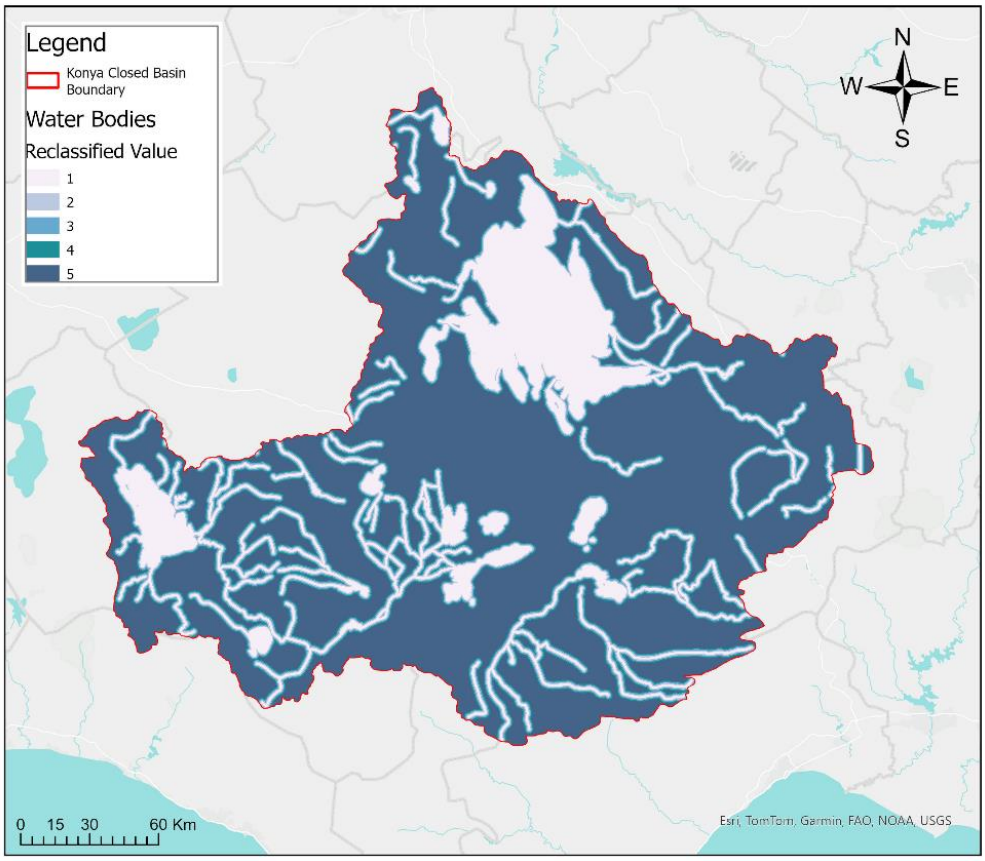

Figure 4.6: Distance from Water Bodies Reclassification Map.

Table 4.8: Distance from Settlements Reclassification.

Criteria	Optimal Interval	Reclassified Value	Suitability Degree
Distance from Settlements	0-500 m & 10000 m<	1	Unsuitable
	500m - 1000m	2	Very Low Suitable
	7000m - 10000m	3	Low Suitable
	4000m - 7000m	4	Moderate Suitable
	1000m - 4000m	5	High Suitable

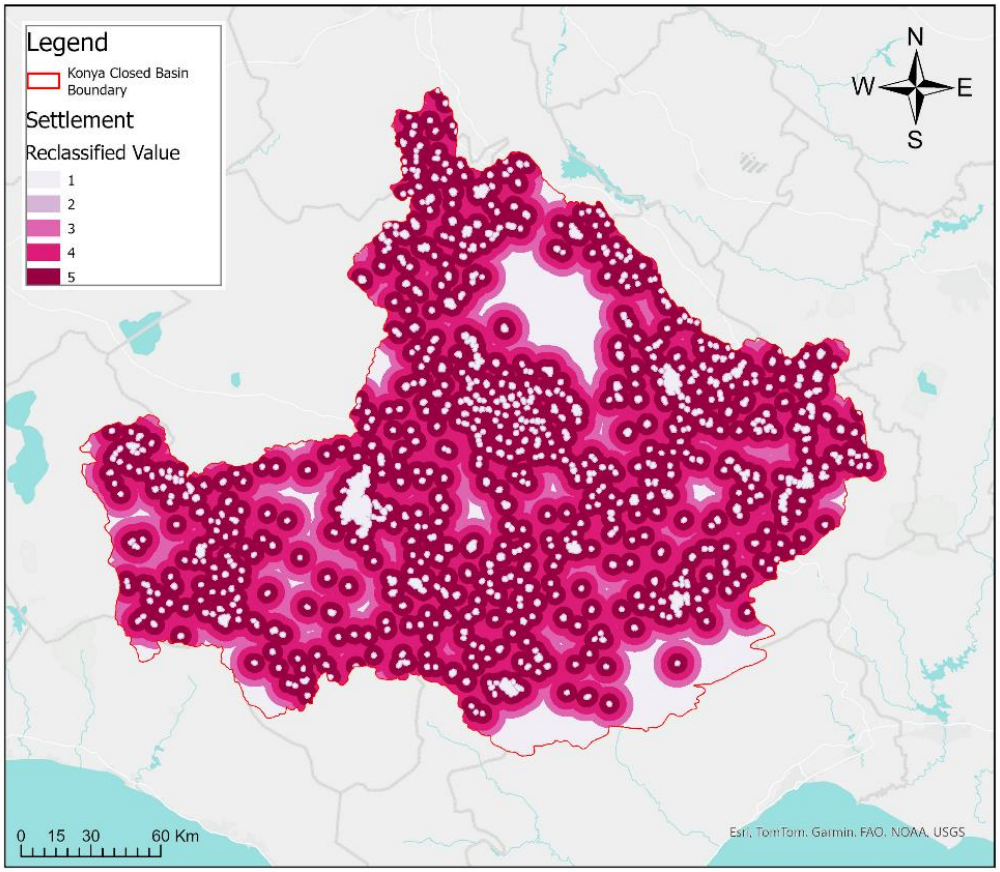

Figure 4.7: Distance from Settlements Reclassification Map.

Table 4.9: Soil Type Reclassification.

Criteria	Optimal Interval	Reclassified Value	Suitability Degree
Soil Type	Calcaric Fluvisols	1	Unsuitable
	Eutric Cambisols, Calcic Cambisols, Calcic Xerosols, Luvic Xerosols, Lithosols	2	Very Low Suitable
	Eutric Regosols	3	Low Suitable
	Gleyic Solonchaks	4	Moderate Suitable
	Orthic Luvisols	5	High Suitable

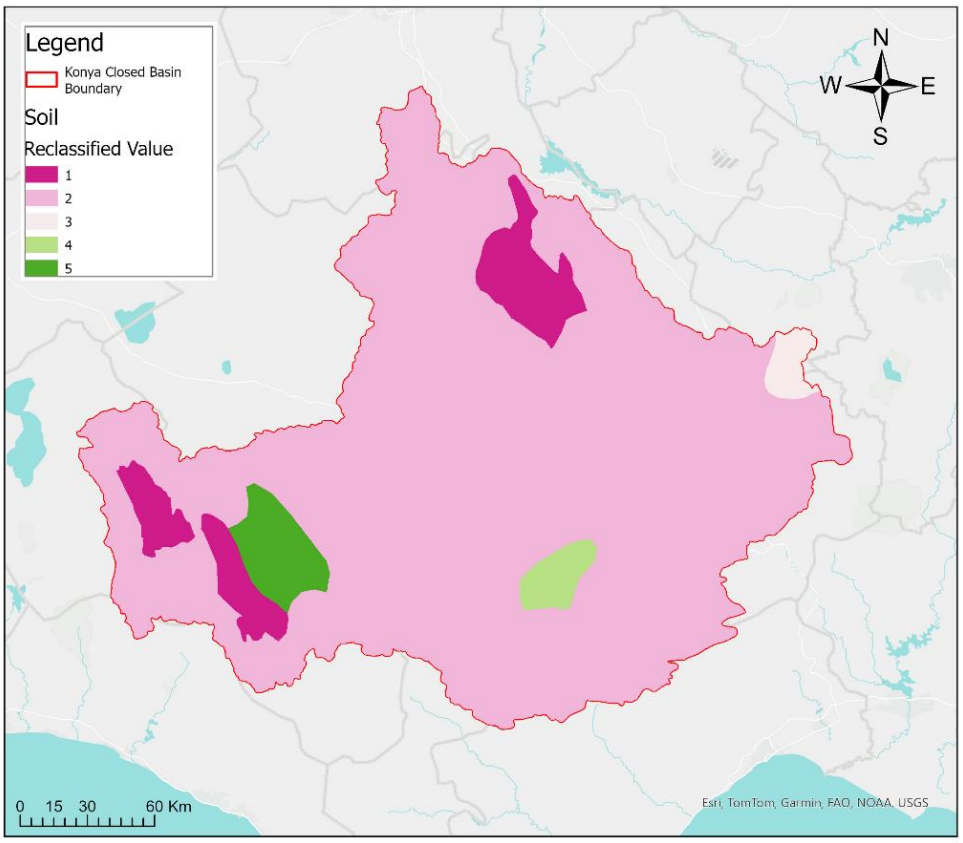

Figure 4.8: Soil Type Reclassification Map.

4.3 Application of the Best-Worst Method

Upon the completion of the production of Exclude and Factor maps, the next crucial step in the process is the calculation of the weights that will be utilized in the analysis. The calculation of these weights is a prerequisite for performing the Weighted Overlay analysis, which serves as the mechanism through which suitable areas are identified.

Each criterion, represented by its respective factor map that is included in the analysis, is assigned a certain weight. These weights are determined based on expert opinions, and the process is conducted within the framework of the Best-Worst Method. The Best-Worst Method is a comprehensive and structured procedure, the details, and steps of which have been elucidated extensively in the preceding sections of this document. For the purposes of this study, considering the discrete nature of our problem, a solver specifically designed for linear Best-Worst Method (BWM) problems was employed. This solver operates within an excel file, which is used to perform the calculations for the weights, based on the inputs provided by the experts.

The excel file used for solving these linear Best-Worst Method problems was created by Razaei (2016), a notable figure in the field and the founder of the method. Included in this document is a figure that showcases a sample excel spreadsheet [52]. Figure 4.9 shows this sample excel spreadsheet filled in according to the author's opinions, however, it's important to note that the author's opinions were not included in the analysis. This ensures the impartiality of the study and maintains the integrity of the results.

Criteria Number = 7	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7
Names of Criteria	Slope of the Site	Elevation	Distance from Road	Land Use / Land	Distance from Water Bodies	Distance from	Soil Type

Select the Best	Distance from Water

Select the Worst	Distance from Road

Best to Others	Slope of the Site	Elevation	Distance from Road	Land Use / Land	Distance from Water Bodies	Distance from	Soil Type
Distance from Water	8	6	9	5	1	2	3

Others to the Worst	Distance from Road
Slope of the Site	2
Elevation	4
Distance from Road	1
Land Use / Land Cover	3
Distance from Water	9
Distance from Settlements	7
Soil Type	6

Weights	Slope of the Site	Elevation	Distance from Road	Land Use / Land	Distance from Water Bodies	Distance from	Soil Type
	0.055398653	0.073864871	0.034759939	0.088637845	0.378014338	0.221594612	0.14772974

Input-Based CR	0.208333333	The pairwise comparison consistency level is acceptable
Associated Threshold	0.3517	

Figure 4.9: Best-Worst Method Solver Excel.

A total of eight experts, including five academicians, two engineers with experience in the field related to wastewater treatment plants, and one geological engineer who has been involved in a wastewater treatment plant project, were consulted for their opinions on the weights of the criteria. The multiplicity of perspectives and the diversity of expertise amongst the consulted experts ensure a well-rounded and robust approach to the weighting process.

Table 4.11 shows the criterion chosen by the decision makers as the best criterion and the subsequent scoring from 1 to 9 against the best criterion. The best criterion naturally receives a value of 1 when compared to itself, whereas it receives a value of 9 when compared to the criterion chosen by the decision maker as the worst criterion.

Table 4.10: Best-to-Others opinions of the decision-makers.

DM ID	Best-to-Others	C1	C2	C3	C4	C5	C6	C7
DM1	C5	4	3	9	5	1	2	7
DM2	C6	5	3	4	2	6	1	9
DM3	C2	9	1	4	8	3	2	5
DM4	C6	8	9	3	5	2	1	7
DM5	C5	7	3	5	9	1	2	6
DM6	C5	9	2	3	7	1	6	5
DM7	C5	8	2	3	6	1	9	5
DM8	C1	1	6	9	7	3	4	2

The comparison scores of the decision makers for the criterion they selected as the worst criterion and then with the other criteria are as shown in Table 4.12. The worst criterion naturally gets a value of 1 when compared with itself, whereas it gets a value of 9 when compared with the criterion chosen by the decision maker as the best criterion.

Table 4.11: Others-to-Worst opinions of the decision-makers.

DM ID	Others-to-Worst	C1	C2	C3	C4	C5	C6	C7
DM1	C3	6	7	1	5	9	8	3
DM2	C7	3	8	5	4	2	9	1
DM3	C1	1	9	6	2	7	8	4
DM4	C2	2	1	7	5	8	9	4
DM5	C4	2	6	5	1	9	7	3
DM6	C1	1	7	6	2	9	3	4
DM7	C6	2	8	6	3	9	1	5
DM8	C3	9	4	1	3	7	5	8

Upon completion of the processes, the next pivotal stage involves the computation of weights and their respective consistency ratios. These weights correspond to each individual criterion that forms an integral part of the analysis.

The computation of weights involves a detailed and meticulous analysis, ensuring that each criterion is given its due consideration in relation to its significance to the overall analysis. This forms the basis of the Weighted Overlay analysis, a crucial component of the suitability assessment process. Following the calculation of weights, the consistency ratios for each weight are then computed. This process ensures that the weights assigned to each criterion are in line with the overall structure and intent of the analysis, thereby maintaining the integrity of the study. This detailed information, including the weights, consistency ratios, and the arithmetic average of the weights, can be found in the designated Table 4.13. The table provides a comprehensive summary of the data, organized in a manner that facilitates easy understanding and interpretation.

Table 4.12: Criteria Weights & Consistency Ratios.

DM ID / Criteria ID	C1	C2	C3	C4	C5	C6	C7	Consistency Ratio
DM1	0.1078	0.1437	0.0308	0.0862	0.3542	0.2156	0.0616	0.2222
DM2	0.0876	0.1460	0.1095	0.2044	0.0730	0.3504	0.0292	0.2083
DM3	0.0310	0.3570	0.1086	0.0543	0.1449	0.2173	0.0869	0.2083
DM4	0.0568	0.0329	0.1515	0.0909	0.2273	0.3755	0.0649	0.2638
DM5	0.0635	0.1483	0.0890	0.0328	0.3699	0.2224	0.0741	0.2222
DM6	0.0348	0.2194	0.1462	0.0627	0.3760	0.0731	0.0877	0.1527
DM7	0.0560	0.2242	0.1495	0.0747	0.3729	0.0330	0.0897	0.2222
DM8	0.3605	0.0727	0.0316	0.0623	0.1455	0.1091	0.2182	0.2083
Average Weight	0.0998	0.1680	0.1021	0.0835	0.2580	0.1995	0.0891	

Subsequently, the arithmetic mean or average of these calculated weights for each criterion is determined. This step is essential in providing a balanced view of the importance of each criterion within the broader context of the analysis. Moreover, this average weight forms the basis for the Weighted Overlay analysis, which is instrumental in generating the suitability map. Table 4.14 shows the final weights of the criterias.

Table 4.13: Final Weights of the Criterias.

Criteria ID	Criteria	Weights
C1	Slope	0.0998
C2	Elevation	0.1680
C3	Distance from Road Network	0.1021
C4	Land Use / Land Cover	0.0835
C5	Distance from Water Bodies	0.2580
C6	Distance from Settlements	0.1995
C7	Soil Type	0.0891

The suitability map is the main purpose of this study and after all this data preparation proceses generated through the Weighted Overlay analysis. The outcomes from this process are then systematically organised into five distinct classes - unsuitable, very low suitability, low suitability, moderate suitability, and high suitability. This classification mirrors the structure employed during the creation of the factor maps, ensuring a consistent approach throughout the analytical process.

The results obtained from the Weighted Overlay analysis [53], along with the final determination of site suitability, are most effectively and visually represented in Figure 4.10, the suitability map. This map serves as a tangible manifestation of our research findings and offers a comprehensive and intuitive visual depiction of the areas that have been deemed most appropriate based on an established set of predetermined criteria. The suitability map is not merely a visual aid, but it serves as an invaluable tool for decision-making, offering a succinct yet thorough overview of the suitability of different areas. The map operates on multiple levels by providing immediate visual cues about the suitability of various areas, while also offering a wealth of underlying data when examined more closely.

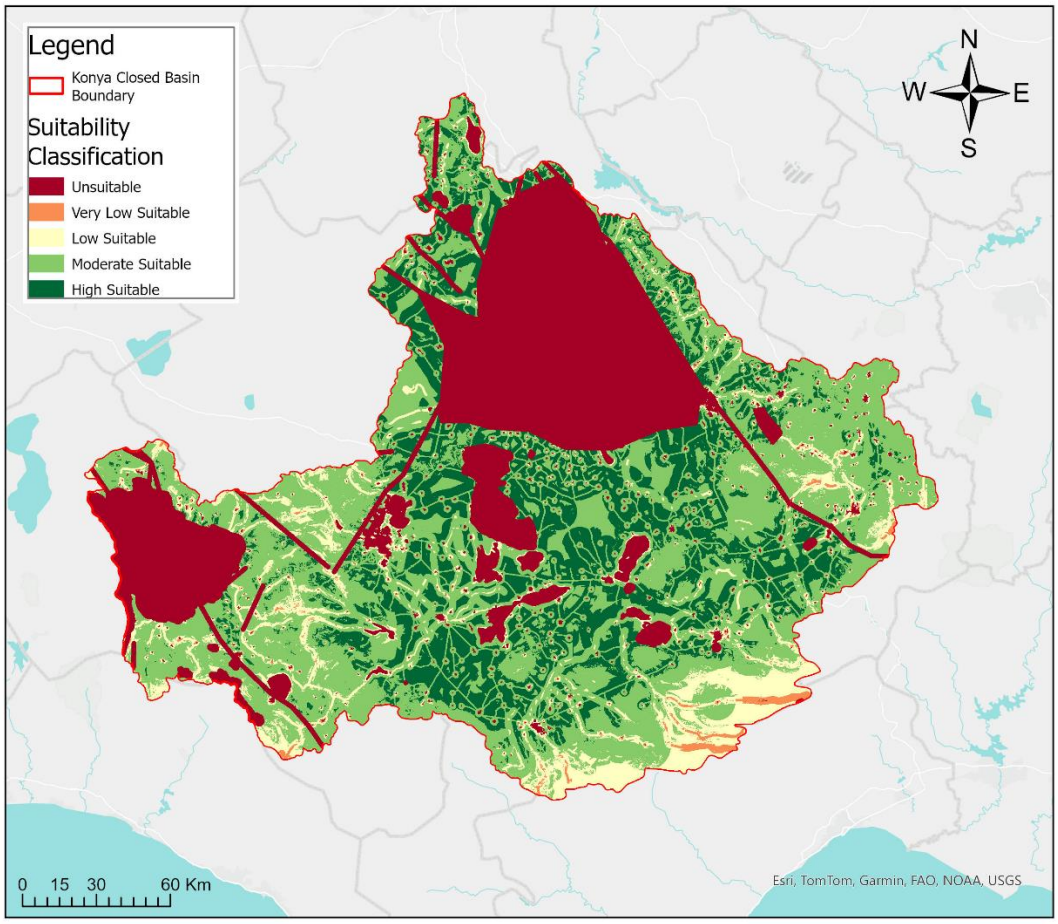

Figure 4.10: Suitability Map for WWTP.

Figure 4.11 shows the percentage distribution of the total area of the Konya Closed Basin, which is the study area, according to the classes in the appropriate map. Unsuitable areas constitute 27.9% of the total area, which is larger than the areas of high suitability, covering 19.5%. This indicates the sensitivity of the region and

underscores the need to carefully consider these unsuitable areas in the selection of sites for wastewater treatment plants. Remarkably, nearly half of the study area (42.5%) is classified as moderately suitable. When combined with the areas of high suitability, a total of 62% of the Konya Closed Basin is deemed suitable for the construction of a wastewater treatment plant.

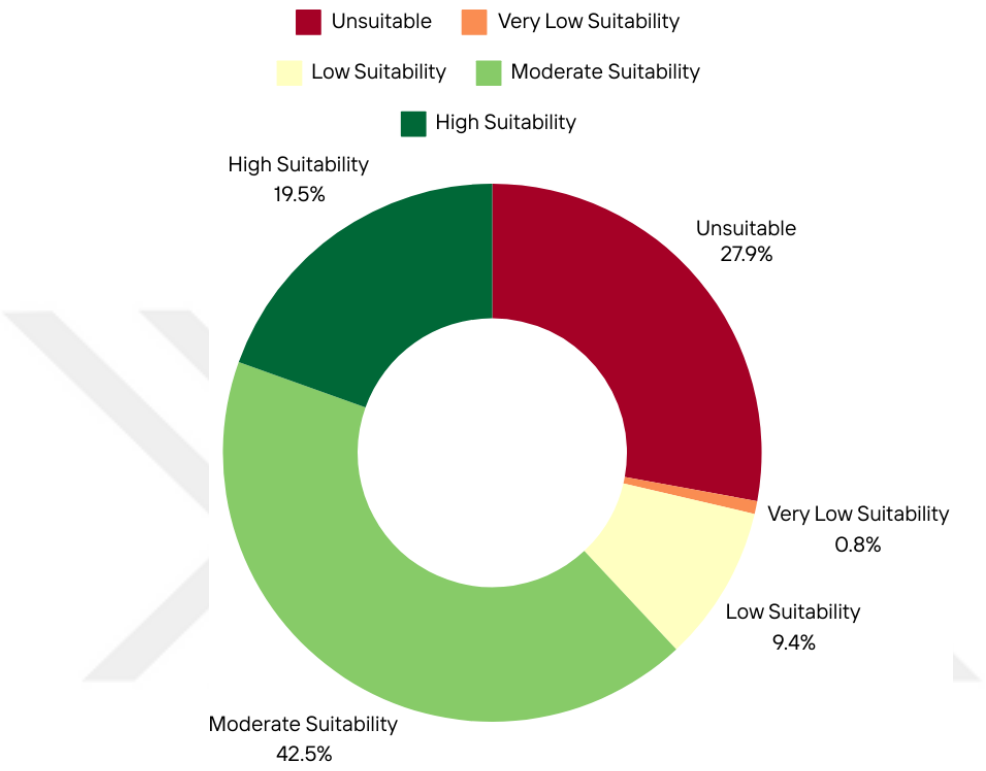

Figure 4.11: Suitability Percentage

In the next section, a sensitivity analysis was performed for each criterion in the GIS environment to test the sensitivity of Figure 4.10 and validate the model.

4.4 Sensivity Analysis

In the context of multi-criteria decision-making analyses that are weighted by expert opinion, such as the Best-Worst Method, it is crucial to acknowledge that the views held by experts, despite their deep knowledge and experience in their respective fields, may still diverge significantly from one another [54]. Moreover, these opinions are subject to change over time due to the dynamism inherent in the research field, the introduction of new information, and the evolution of individual perspectives.

Sensitivity analysis, a sophisticated methodological approach, is designed specifically to assess the resilience of the outcomes generated by such multi-criteria decision-making analyses. This analysis is instrumental in scrutinizing how the assumptions that underpin the decision-making process hold up under varying conditions and parameters. The primary function of sensitivity analysis is to provide a systematic exploration of the potential impacts that alterations in the examined criteria might have on the overall system and the ensuing decision mechanism. By doing so, it affords valuable insights into the robustness of the decision-making process, bringing to light the extent to which modifications in the criteria could influence the final decision. In essence, sensitivity analysis serves as a critical tool in the decision-making arsenal, offering a rigorous and robust means to investigate the flexibility and adaptability of the decision that emerges from these assumptions. By facilitating a comprehensive understanding of the potential variations in the decision outcomes, sensitivity analysis plays a pivotal role in enhancing the reliability and credibility of decision-making processes. Thus, it is an indispensable component in the realm of multi-criteria decision-making analyses [55].

The process of sensitivity analysis is one of the integral parts of our methodology and following equations (4.1) used for it.

$$\omega_j = (1 - \omega_i) * \left(\frac{\omega_j^0}{(1 - \omega_i^0)}\right) \tag{4.1}$$

ω_j; j represents the revised weight of the respective criterion, which will be employed in the subsequent sensitivity analysis. ω_i represents the adjusted weight of the *i.* criterion, subjected to either a decrease or increase within the sensitivity analysis. The variables ω_i^0 and ω_j^0 denote the original weights assigned to the *i.* and *j.* criteria, respectively, prior to the application of the sensitivity analysis [56].

In the study conducted by Erden (2009), the sensitivity analysis was performed in increments of 20%, and this approach yielded effective results. Therefore, in the current study, weight changes of 0%, 20%, 40%, 60%, 80%, and 100% were applied to each criterion. The Weighted Overlay analysis was then redone, recalculating the other criteria each time to maintain a total result of 100% [56]. Following this procedure, the weight values calculated for each criterion were applied. For the 'slope' criterion, reference can be made to Table B.1, for the 'elevation' criterion, see Table B.2, for the 'distance from road network' criterion, check Table B.3, for the 'land use /

land cover' criterion, refer to Table B.4, for the 'distance from water bodies' criterion, Table B.5 can be consulted, for the 'distance from settlements' criterion, please look at Table B.6, and finally, for the 'soil type' criterion, Table B.7 provides the required information.

It is important to note that this rigorous process of conducting sensitivity analysis with weight changes in the identified increments is integral to the study. It ensures a comprehensive understanding of the varying impacts that different weight assignments can have on the outcome of the suitability analysis.

For instance, when implementing six distinct sensitivity analyses on the 'distance from water bodies' criterion, which possesses the highest weight at a value of 26%, we observe the most stable results within weight ranges of 20% to 40%. Interestingly, when this weight is amplified to 100%, the areas identified as suitable for site selection become predominantly elevated. A significant reduction in the area covered by suitable locations is noted when the weight decreases from 80% to 60%. These variations confirm the effective functioning of the analytical results. In the aggregate, 42 different analytical outcomes were charted within the ArcGIS Pro software. These can be examined in Appendix C, delineated as Figure C.1, Figure C.2, Figure C.3, Figure C.4, Figure C.5, Figure C.6, and Figure C.7, respectively. These figures present a comprehensive visual representation of the data, facilitating a nuanced understanding of the suitability of different areas. The detailed information contained within these figures, including the weights, consistency ratios, and arithmetic means, serves as an essential guide in the decision-making process. It provides us with valuable insights that can be used to make informed and accurate decisions.

5. RESULTS & DISCUSSIONS

The suitability analysis of the Konya Closed Basin reveals important insights into its potential for wastewater treatment plant (WWTP) construction. This analysis, derived from a meticulous assessment of various criteria, indicates that a significant proportion of the area, precisely 27.9%, is classified as unsuitable for WWTP site selection. This unsuitable classification, which covers a larger area than the high suitability areas that account for 19.5%, denotes areas that exhibit characteristics rendering them sensitive or unsuitable for such developments. The unsuitable characteristics could range from environmental considerations, geographical constraints, to socio-economic factors. This finding underscores the importance of a thorough and detailed suitability analysis in the planning stages of WWTP site selection. It highlights the need to carefully consider and navigate the complexities and sensitivities of the area to ensure sustainable and responsible development.

In contrast, the analysis also reveals that a significant portion of the study area, approximately 42.5%, is classified as moderately suitable for WWTP construction. This classification indicates that almost half of the Konya Closed Basin exhibits factors and conditions that could potentially accommodate and sustain the development of a WWTP, subject to further detailed site-specific studies and assessments. Furthermore, when we consider the areas classified as high suitability, which constitute 19.5% of the area, we find that a total of 62% of the Konya Closed Basin could potentially be considered for the construction of a wastewater treatment plant. This cumulative figure, which combines the areas of moderate and high suitability, provides a comprehensive view of the potential for WWTP development in the Konya Closed Basin. The examination of the results provides a clear illustration that the regions delineated as highly suitable for the development of a wastewater treatment plant are predominantly situated in the central part of the Konya Closed Basin. On the other hand, regions that have been assessed as unsuitable, and therefore not recommended for such developmental initiatives, are primarily concentrated in the vicinity of Tuz

Lake and Beyşehir Lake. This spatial distribution of suitable and unsuitable zones necessitates careful consideration and strategic planning in the pursuit of sustainable wastewater treatment plant construction within the Konya Closed Basin.

As can be discerned from Figure 5.1, the Konya Closed Basin is home to a total of 24 wastewater treatment plants. A rigorous suitability analysis was undertaken to assess the appropriateness of the sites where these plants have been constructed. This analysis revealed that only three of these wastewater treatment facilities occupy locations classified as highly suitable. Interestingly, seven of the plants are situated within moderately suitable areas, three are in low suitability areas, and one is in a very low suitability area. A cause for concern is that 10 of the plants are in areas deemed unsuitable. This finding, that almost half of the wastewater treatment plants within the area are situated in locations that have been designated as unsuitable, suggests that the current situation is far from ideal. However, this research can serve as a valuable guide for future decisions related to site selection.

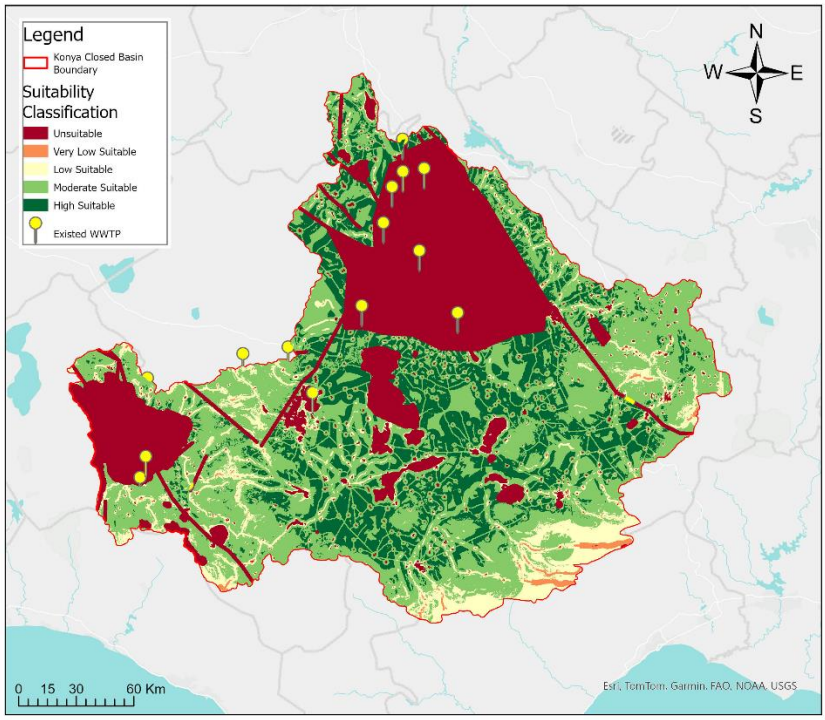

Figure 5.1: Suitability Analysis Results with Existed WWTP Locations.

Figure 5.2 (a) provides a visual representation of the locations of both the highly suitable areas and the existing wastewater treatment plants. Meanwhile, Figure 5.2 (b) illustrates the unsuitable areas and pinpoints the locations of the wastewater treatment

plants currently in operation. It is noteworthy to mention that many of the wastewater treatment plants that have opted for unsuitable locations are primarily situated in and around Tuz Lake. Despite Tuz Lake and its surrounding areas being designated as part of the Special Environmental Protection Area (SEPA) due to its marshy topography, which led to its direct exclusion from the analysis, a substantial number of wastewater treatment plants have been established in these regions. This highlights a palpable need for more facilities within this environment. Given this scenario, it is recommended that future site selection for facility construction should place greater emphasis on evaluating the high or moderate suitable areas that are in closest proximity to this region. This will ensure that the demand for such facilities is effectively addressed while also adhering to the constraints set by environmental and suitability considerations.

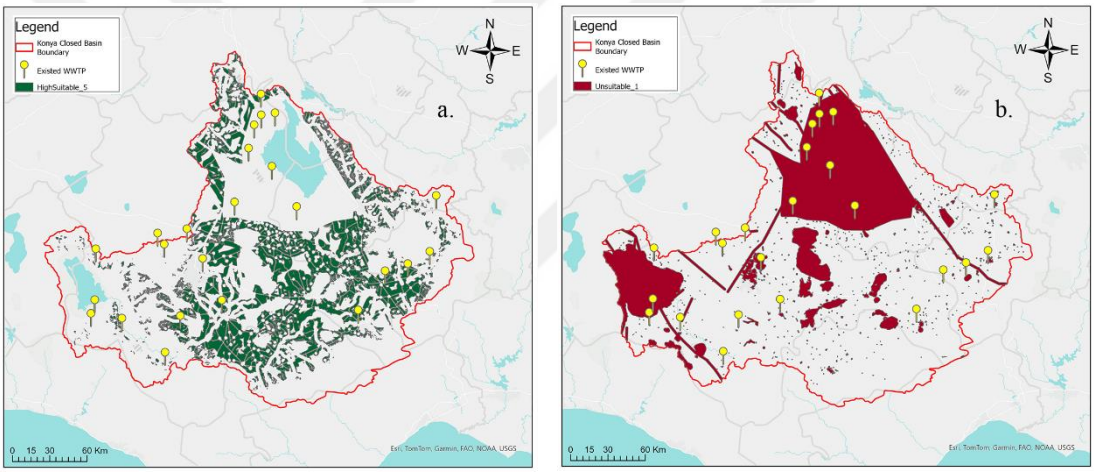

Figure 5.2: Existed WWTP Locations with High Suitable Areas (a), Existed WWTP Locations with Unsuitable Areas (b).

In the process of analyzing the suitability of the Konya Closed Basin for the construction of wastewater treatment plants (WWTP), an additional thougts of consideration was incorporated: the proximity of potential sites to agricultural lands. The strategic view of wastewater treatment plants in close vicinity to agricultural lands was considered to potentially yield significant advantages. One such advantage was the possibility of repurposing treated wastewater for irrigation purposes. This concept of resource recycling could have led to a more sustainable approach to agricultural practices, contributing to resource conservation and environmental sustainability.

However, the proximity of wastewater treatment plants to agricultural lands was not without its potential drawbacks. The primary concern revolved around the risk of contamination. While treated wastewater could indeed serve as a valuable resource for irrigation, it was critical to ensure that the treatment process was adequate and effective in removing harmful contaminants. If not, these contaminants could have potentially infiltrated agricultural lands, leading to a range of adverse effects on soil health, crop quality, and by extension, human health.

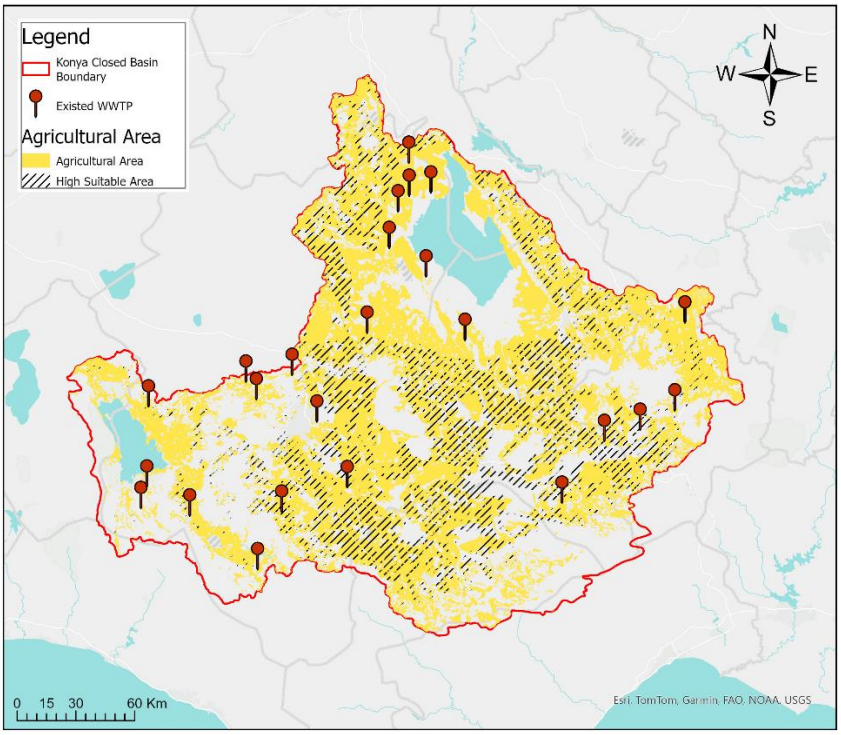

Figure 5.3: Konya Closed Basin Agricultural Area with Existed WWTP Locations.

Figure 5.3 offered a comprehensive depiction of all regions within the Konya Closed Basin that were associated with agricultural activities, along with the locations of existing wastewater treatment plants and areas identified as highly suitable. As evidenced in the map, agricultural regions constituted approximately 70% of the total area, reaffirming the rationale behind the decision to conduct this study in the Konya Closed Basin. One of the primary objectives of the study had been to propose an alternative solution to the pressing issue faced in regions characterized by a high prevalence of agricultural activities, yet simultaneously plagued by a scarcity of clean water. It was in accordance with this objective that the proximity of highly suitable areas to agricultural regions was considered during the suitability analysis. The results,

as depicted in Figure 5.3, indicated that this objective had been successfully achieved, with high suitability areas located conveniently close to agricultural regions. However, it was important to also note that the highest concentration of both highly suitable areas and agricultural lands was observed within the central region of the Konya Closed Basin. This significant finding required careful consideration and emphasized the need for strategic planning in the selection of future sites for wastewater treatment plant construction.

Given these potential benefits and risks, a strategic and carefully considered approach was deemed essential when evaluating suitable areas for WWTP construction near agricultural lands. This necessitated a comprehensive analysis that considered not just the geographical and environmental suitability of potential sites, but also the potential impact on adjacent agricultural lands. The objective was to strike a balance between the optimization of resources and the preservation of the surrounding environment. This balance prioritized both the sustainable use of water resources and the maintenance of the safety and integrity of agricultural lands and the broader environment.

In conclusion, this rigorous suitability analysis of the Konya Closed Basin offers critical insights into the potential locations for wastewater treatment plant construction. It underscores the need for careful planning and consideration of a range of factors to ensure sustainable and responsible development. While a significant portion of the area is unsuitable, the analysis reveals that most of the area could potentially accommodate such a development, demonstrating the feasibility of WWTP construction in the Konya Closed Basin.

6. CONCLUSION & RECOMMENDATIONS

The conclusion of the study focused on the site selection for the Wastewater Treatment Plant (WWTP) in the Konya Closed Basin, which was identified as a complex process involving numerous factors. The tools that were employed and found to be of crucial importance in this process were the Geographic Information Systems (GIS) and the Best-Worst Method. These facilitated the optimization of the decision-making process.

The importance of maintaining updated data was emphasized as it plays a critical role in determining suitable areas, particularly as land topography may undergo changes over time. The incorporation of Geographic Information Systems (GIS) with a robust multi-criteria decision-method, such as the Best Worst Method, enhanced the process of analyzing and visualizing suitable locations for WWTPs. This became a more streamlined and efficient process. The potential for automating this process was identified, which would significantly increase efficiency within the waste management sector and expedite the construction process.

It was also noted that site selection models are unique to each application, therefore the selection of criteria and method will differ with each problem. This study provided a clear answer to the question of how a site selection process using BWM works. The results obtained were reliable and strongly mirrored the real-life situation.

The potential for extending this study was also identified, particularly in applying the Analytic Hierarchy Process (AHP) as a multi-criteria decision-making method along with BWM. This would allow for a comparison of their reliability and consistencies and could help determine how effective each method is when the number of criteria is relatively low. This is particularly relevant as one of the benefits of BWM is its requirement for fewer pairwise comparisons.

In the process of determining the weights of the criteria, the study did not solely rely on the opinions of academic experts. Instead, it also considered the views of engineers who have had practical field experience. This approach increased the objectivity in

determining the criteria and allowed for possible changes in the criteria weighting process to be observed by increasing the number of people participating in the evaluation.

The culmination of this research study stands as a significant milestone in the expanding body of academic literature pertaining to the application of the Best-Worst Method (BWM) within the wastewater management sector. It has successfully unveiled deeper insights into the intricate process of site selection, thereby throwing light on the judicious application of advanced methodologies and the importance of selecting the right criteria.

Moreover, this study has paved an academic pathway for prospective research endeavors, providing them a robust foundation upon which to base their choice of criteria, the multi-criteria decision-making technique, and the process of data management for site selection across diverse disciplines.

The comprehensive approach adopted in this research, which meticulously combines innovative methodologies, accurate data processing, and strategic decision-making practices, has underscored the potential for optimisation of resource utilisation. It has also highlighted the importance of strategic decision-making methods, thereby contributing significantly to the broader discourse on efficient and sustainable wastewater management strategies.

The successful completion of this research, therefore, serves as a testament to the transformative potential of integrating advanced Geographic Information Systems (GIS), the Best-Worst Method, and strategic decision-making in the environmental management and wastewater treatment sectors. It is a significant step forward in advancing our understanding of the complexities involved in site selection processes and the potential strategies to address them effectively.

To summarise, this research study, through its groundbreaking findings and insights, has made a substantial contribution to the existing literature on wastewater management. It has opened new avenues for future research and has provided a blueprint for more effective resource utilisation and strategic decision-making in the context of environmental management.

REFERENCES

[1] **Auta, H., Emenike, C., & Fauziah, S.** (2017). Distribution and importance of microplastics in the marine environment: A review of the sources, fate, effects, and potential solutions. *Environment International*, 102: 165-176. doi:10.1016/j.envint.2017.02.013

[2] **Saraoğlu, E.** (June 2014). *Arıtılmış Atıksuların Tarımsal Sulamada Yeniden Kullanımı - Ülkemizden ve Dünyadan Başarılı Örnekler ve Türkiye için Uygulama Önerileri.* Çevre Şehircilik Bakanlığı, Çevre Yönetim Genel Müdürlüğü Su ve Toprak Yönetimi Dairesi Başkanlığı Raporu.

[3] **Adalı, S., & Kılıç, M. Y.** (2020). Arıtılmış Atıksuların Tarımsal Sulamada Kullanımı: İznik Örneği. *Uluslararası Biyosistem Mühendisliği Dergisi*, 12-23.

[4] **Direk, M., Güngör, L., & Acar, R.** (2022). Atıksuyun Önemi, Değeri ve Tarım ile İlişkisi. *Ulusal Çevre Bilimleri Araştırma Dergisi*, 47-54. doi:Orcid:0000-0002-7232-9089

[5], **Ç. M.** (2023). *Konya Havzası Stratejik Çevre Değerlendirme Raporu.* Ankara: Tarım ve Orman Bakanlığı Su Yönetimi Genel Müdürlüğü.

[6] **Berke, M. Ö., Dıvrak, B. B., & Sarısoy, H. D.** (2014). *Konya'da Suyun Bugünü.* WWF Türkiye.

[7] **Ak, M., & Top, İ.** (2018). Arıtılmış kentsel atıksuların tarımsal sulama amaçlı kullanımı. *Pamukkale Üniversitesi Mühendsilik Bilimleri Dergisi*, 24 (6): 1161-1168. doi:10.5505/pajes.2017.89577

[8] **Kınık, Z., & Aykaç, Z.** (2021). Atıksu Arıtma Tesislerinde Karşılaşılan Problemler ve Çözüm Önerileri. *Türk Hidrolik Dergisi*, 5 (1): 59-65. doi:ORCID: 0000-0001-9737-9106; 0000-0002-5242-0002

[9] **Pedrero, F., & ..., I. K.** (2010). Use of treated municipal wastewater in irrigated agriculture, Review of some practices in Spain and Greece. *Agricultural Water Management*, 97: 1233-1241. doi:10.1016/j.agwat.2010.03.003

[10] **Url-1** Food and Agriculture Organization of the United, N. (n.d). *FAO*. Retrieved April 23, 2024, from Wastewater treatment and reuse in agriculture: https://www.fao.org/land-water/water/water-management/wastewater/en/

[11] **Url-2.** (2009, Ekim 10). *T.C. Cumhurbaşkanlığı Mevzuat Bilgi Sistemi*. Retrieved April 23, 2024, from SU KİRLİLİĞİ KONTROLÜ YÖNETMELİĞİ NUMUNE ALMA VE ANALİZ METODLARI TEBLİĞİ: https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=13482&MevzuatTur=9&MevzuatTertip=5

[12] **Zhao, D.** (2015). *Using GIS-based Multi-criteria Analysis for Optimal Site Selection for a Sewage Treatment Plant.* Faculty of Engineering and Sustainable Development Department of Industrial Development, IT and Land Management.

[13] **Mansouri, Z., Moghaddas, N. H., & Dahrazma, B.** (2013). Wastewater treatment plant site selection using AHP and GIS: a case study in Falavarjan, Esfahan. *Geopersia*, 3 (2): 63-72. doi:10.22059/JGEOPE.2013.36015

[14] **Taghilou, S., Peyda, M., Khosravi, Y., & Mehrasbi, M. R.** (2019). Site Selection for Wastewater Treatment Plants in Rural Areas Using the Analytical Hierarchy Process and Geographical Information System. *Journal of Human, Environment, and Health Promotion*, 5(3): 137-144. doi:10.29252/jhehp.5.3.8

[15] **Abdalla, O. O., & Khidir, S. O.** (2017). Site Selection of Wastewater Treatment Plant using RS/GIS data and Multi-Criteria Analysis (MCA): Case Study Omdurman City, Khartoum State, Sudan. *Alneelain Journal of Geosciences*, 1 (2): 94-107. doi:ISSN: 1858-7801

[16] **Shahmoradi, B., & Isalou, A. A.** (2013). Site selection for wastewater treatment plant using integrated fuzzy logic and multicriteria decision model, A case study in Kahak district. *Journal of Advances in Environmental Health Research*, 1 (1): 1-11.

[17] **Anagnostopoulos, K., & Vavatsikos, A.** (2012). Site Suitability Analysis for Natural Systems for Wastewater Treatment with Spatial Fuzzy Analytic Hierarchy Process. *Journal of Water Resources Planning and Management*, 138: 125-134. doi:10.1061/(ASCE)WR.1943-5452.0000155

[18] **Fallah, M., Vagharfard, H., Farajzadeh, M., & kheslat, A. N.** (2014). Assessment of Spatial multi-criteria decision-making with process of the artificial neural networks Method to Site Selection of the Wastewater Treatment Plant (Case study: Qeshm Island). *International journal of Advanced Biological and Biomedical Research*, 2 (6): 2061-2066.

[19] **Aydi, A., Abichou, T., Nasr, I. H., Louati, M., & Zairi, M.** (2016). Assessment of land suitability for olive mill wastewater disposal site selection by integrating fuzzy logic, AHP, and WLC in a GIS. *Environmental Monitoring and Assessment*, 188: 59. doi:10.1007/s10661-015-5076-3

[20] **M.A, G., & Ebraheem, J.** (2012). Location Optimization of Wastewater Treatment Plants Using GIS: A Case Study in Umm Durman/Karary. *Annual Conference of Postgraduate Studies and Scientific Research (Basic and Engineering Studies Board), Friendship Hall, Khartoum*, (pp. 1-9). Khartoum.

[21] **Zhao, Y., Qin, Y., Chen, B., Zhao, X., Li, Y., Yin, X., & Chen, G.** (2009). GIS-based optimization for the locations of sewage treatment plants and sewage outfalls – A case study of Nansha District in Guangzhou City, China. *Communications in Nonlinear Science and Numerical Simulation*, 14: 1746–1757. doi:10.1016/j.cnsns.2007.12.016

[22] **Deepa, K., & Krishnaveni, M.** (2012). Suitable Site Selection of Decentralised Treatment Plants Using Multicriteria Approach in GIS. *Journal of Geographic Information System*, 4: 254-260. doi:10.4236/jgis.2012.43030

[23] **Zhou, Y., Song, Y., Li, S., Qin, W., & Sun, J.** (2022). A Location Selection Method for Wastewater Treatment Plants Integrating Dynamic Change ofWater Ecosystem and Socio-Cultural Indicators: A Case Study of Phnom Penh. *Water Journal*, 14: 3637. doi:10.3390/w14223637

[24] **Anagnostopoulos, K., & Vavatsikos, A.** (2007). Using GIS and Fuzzy Logic for Wastewater Treatment Processes Site Selection: The Case of Rodopi Prefecture. *Computation in Modern Science and Engineering, Proceedings of the International Conference on Computational Methods in Science and Engineering*, (p. Vol. 2 Part B). Greece.

[25] **Asefa, B., & Mindahun, W.** (2019). Geospatial Based Optimum Site Selection for Wastewater Treatment Plant: The Case of Debre Berhan Town, Amhara Regional State, Ethiopia. *Journal of Geosciences and Geomatics*, 7 (3): 97-104. doi:10.12691/jgg-7-3-1

[26] **Ghasemi, A., Saghafian, B., & Golian, S.** (2017). Optimal location of artificial recharge of treated wastewater using fuzzy logic approach. *Journal of Water Supply: Research and Technology—AQUA*, 1 (1): 1-11. doi:10.2166/aqua.2017.049

[27] **Hama, A. R., Al-Suhili, R. H., & Ghafour, Z. J.** (2019). A multi-criteria GIS model for suitability analysis of locations of decentralized wastewater treatment units: case study in Sulaimania, Iraq. *Heliyon Journal*, 5: e01355. doi:10.1016/j.heliyon.2019.e01355

[28] **Addis, A.** (2021). Selection of Wastewater Treatment Plant Site for Bahir Dar Town, Ethiopia Using Multi-Criteria Analysis on GIS platform. *Journal of Civil and Environmental Research*, 13 (3): 9-16. doi:ISSN: 2225-0514

[29] **Nigusse, A. G., Adhaneom, U. G., Kahsay, G. H., Abrha, A. M., Gebre, D. N., & Weldearegay, A. G.** (2020). GIS application for urban domestic wastewater treatment site selection in the Northern Ethiopia, Tigray Regional State: a case study in Mekelle City. *Arabian Journal of Geosciences*, 13: 311. doi:10.1007/s12517-020-5257-4

[30] **D'Andrea, M. L., Iribarnegaray, M. A., & vd., W. A.** (2021). Multi-Criteria Assessment Model to Identify Suitable Areas for Treated Waste Water Reuse in Agriculture. *Revista Internacional De Contaminacion Ambiental (Uluslararası Çevre Kirliliği Dergisi)*, 37: 513-525. doi:10.20937/RICA.53749

[31] **Ansari, M., Fahiminia, M., Ahmadi, R. M., & Ahmadi, E.** (2017). Evolution Site Selection by Using an Analytical Hierarchy Process for Decentralized Wastewater Treatment Plants in the City of Qom, Iran. *Journal of Environmental Health and Sustainable Development*, 2 (2): 282-289.

[32] **Subramani, T., Subramanian, A., Kathirvel, C., & Devi, S. K.** (2014). Analysis and Site Suitability Evaluation for Textile Sewage Water Treatment Plant in Salem Corporation, Tamilnadu Using Remote Sensing Techniques. *Int. Journal of Engineering Research and Applications*, 8 (6): 90-102.

[33] **Koyuncu, İ., Öztürk, İ., Aydın, A. F., & ..., K. A.** (2013). *Atıksu Arıtma Tesisleri Tasarım Rehberi.* Orman ve Su İşleri Bakanlığı Su Yönetimi Genel Müdürlüğü.

[34] **Jalabhavan, V. T.** (2021). *GIS-Based Multi Criteria Analysis for Optimal Sites Selection for a Sewage Treatment Plant - A case Study at Elamkulam, Kochi, Kerala.* Kerala Water Authority.

[35] **Sammy, D. N.** (2018). *Use of Geospatial Technologies in the Selection of Suitable Sites for a Wastewater Treatment Plant.* Nairobi: University of Nairobi, School of Engineering.

[36] **Roy, B.** (1996). *Multicriteria Methodology for Decision Aiding.* SPRINGER-SCIENCE+BUSINESS MEDIA, B.V. doi:10.1007/978-1-4757-2500-1

[37] **Hamed Taherdoost, M. M.** (2023). Multi-Criteria Decision Making (MCDM) Methods and Concepts. *Encyclopedia*, 3: 77-87. doi:10.3390/encyclopedia3010006

[38] **Aleksandra Baczkiewicz, J. W.** (2021). Towards Objectification of Multi-Criteria Assessments: a Comparative Study on MCDA Methods. *Proceedings of the 16th Conference on Computer Science and Intelligence Systems*, (pp. 25: 417-425). doi:10.15439/2021F61

[39] **Rezaei, J.** (2015). Best-worst multi-criteria decision-making method. *OMEGA*, 1 (1): 49-57. doi:10.1016/j.omega.2014.11.009

[40] **Akyüz, G., Tosun, Ö., & Aka, S.** (2020). Performance Evaluation of Non-Life Insurance Companies With Best-Worst Method and TOPSIS. *Int. Journal of Management Economics and Business*, 16 (1): 108-125. doi:10.17130/ijmeb.700907

[41] **Jiaqin Yang, H. L.** (1997). An AHP decision model for facility location selection. *Facilities*, 15: 241-254. doi:10.1108/02632779710178785

[42] **Url-3**, L. S. (2020, June 14). *Kuş Notları*. Retrieved April 23, 2024, from Konya Kapalı Havzası Kuş Atlası: https://kusnotlari.wordpress.com/2020/07/14/konya-kapali-havzasi-kus-atlasi/

[43] **Url-4**. (n.d.). *USGS*. Retrieved October 01, 2023, from EarthExplorer: https://earthexplorer.usgs.gov/

[44] **Url-5.** (2023). *Open Street Map*. Retrieved October 01, 2023, from https://www.openstreetmap.org/

[45] **Url-6.** (2018). *Copernicus Land Monitoring Service*. Retrieved October 01, 2023, from Urban Atlas: https://land.copernicus.eu/en/products/urban-atlas

[46] **Url-7**. (1977). *Food and Agriculture Oranization of the United Nations*. Retrieved October 01, 2023, from FAO/UNESCO Soil Map of the World: https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/faounesco-soil-map-of-the-world/en/

[47] **Url-8**. (2021). *ArcGIS Living Atlas*. Retrieved October 01, 2023, from Global Active Earthquake Faults: https://esriturkiye.maps.arcgis.com/home/item.html?id=37a384d4c1ef4f56a33a40f291a634e9

[48] **Url-9**. (2020). *Kürşat ÖZCAN Kişisel Web Sayfası*. Retrieved October 01, 2023, from Korunan alanlar, milli parklar, tabiat anıtları, yaban hayatını geliştirme sahaları ve sulak alanlar: https://www.kursatozcan.com/korunan_alanlar/

[49] **Url-10**. (n.d.). *ArcGIS Pro*. Retrieved November 28, 2023, from Reclassify (Spatial Analyst): https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/reclassify.htm

[50] **Url-11**. (n.d.). *ArcGIS Pro*. Retrieved November 28, 2023, from Buffer (Analysis): https://pro.arcgis.com/en/pro-app/latest/tool-reference/analysis/buffer.htm

[51] **Url-12**. (n.d.). *ArcGIS Pro*. Retrieved November 28, 2023, from Merge (Data Management): https://pro.arcgis.com/en/pro-app/latest/tool-reference/data-management/merge.htm

[52] **Url-13**. (2016). *Solver Linear BMW*. Retrieved December 12, 2023, from https://bestworstmethod.com/software/

[53] **Url-14**. (n.d.). *Weighted Overlay (Spatial Analyst)*. Retrieved January 05, 2024, from https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/weighted-overlay.htm

[54] **Nyimbili, P. H., & Erden, T.** (2021). Comparative evaluation of GIS-based best–worst method (BWM) for emergency facility planning- perspectives from two decision-maker groups. *Natural Hazard*, 105: 1031-1067. doi:10.1007/s11069-020-04348-3

[55] **Demir, G., & Arslan, R.** (2022). Sensitivity Analysis in Multi-Criteria Decision-Making Problems. *Ankara Hacı Bayram Veli Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 24(3): 1025-1056.

[56] **Erden, T.** (2009). *Coğrafi Bilgi Sistemleri ile Analitik Hiyerarşi Yöntemi'ne Dayalı İtfaiye İstasyon Yer Seçimi: İstanbul Örneği.* İstanbul: İstanbul Teknik Üniversitesi Doktora Tezi.

APPENDICES

APPENDIX A: Literature Table
APPENDIX B: Sensitivity Tables
APPENDIX C: Sensitivity Maps

APPENDIX A

Table A.0.1: Literature Review Summary of Site Selection for WWTP.

Ref No	Title of the Study	Year	Method of Analysis	Purpose
[14]	Site Selection for Wastewater Treatment Plants in Rural Areas Using the Analytical Hierarchy Process and Geographical Information System	2019	AHP	Site selection for an optimum WWTP site is being conducted in the rural areas of the Zanjanrood basin in Iran's Zanjan province.
[13]	Wastewater treatment plant site selection using AHP and GIS: a case study in Falavarjan, Esfahan	2013	AHP, Fuzzy Hierarchical Analysis, GIS	The goal of this study is to reduce environmental contamination as urban populations grow, as does public health and awareness. As a result, it has become critical to clean wastewater and recover water for future use, including agricultural uses.
[15]	Site Selection of Wastewater Treatment Plant using RS/GIS data and Multi-Criteria Analysis (MCA): Case Study Omdurman City, Khartoum State, Sudan	2017	AHP, GIS, RS	Omdurman is one of Sudan's major cities in terms of territory and population, and it continues to grow. This causes significant environmental difficulties and risks. One of the city's major environmental issues is a lack of modern and effective Wastewater Treatment Plants (WWTP). The study aims to minimize pollution by correcting this shortcoming.

Table A.0.2 (continued): Literature Review Summary of Site Selection for WWTP.

[12]	Using GIS-based Multi-criteria Analysis for Optimal Site Selection for a Sewage Treatment Plant	2015	AHP, GIS, RS	The study's purpose, like other environmental concerns, is to prevent water contamination. The study region is an important metropolis in Sichuan province in southwest China.
[16]	Site selection for wastewater treatment plant using integrated fuzzy logic and multicriteria decision model, A case study in Kahak district	2013	ANP, Fuzzy Logic	Finding a suitable location for the development of infrastructure such as water and wastewater treatment plants is one of the environmental challenges of urban planning. The goal of this study is to identify a site in the designated study region by combining two separate methodologies.
[17]	Site Suitability Analysis for Natural Systems for Wastewater Treatment with Spatial Fuzzy Analytic Hierarchy Process	2012	SPAHP (Spatial Fuzzy AHP), GIS	The research paper describes a methodology for employing the SFAHP technique to enable raster-based land use suitability investigations. The research region is in northern Greece and promotes the use of treated wastewater in agriculture.
[18]	Assessment of Spatial multi-criteria decision-making with process of the artificial neural networks Method to Site Selection of the Wastewater Treatment Plant (Case study: Qeshm Island)	2014	ANN (Artificial Neural Networks), GIS	It aims to determine the placement of facilities that will treat wastewater created by humanity's growing daily water demands, yet natural resources are becoming more insufficient to supply this need. Qeshm, an island in the Persian Gulf, was chosen as the research area.

Table A.0.3 (continued): Literature Review Summary of Site Selection for WWTP.

[19]	Assessment of land suitability for olive mill wastewater disposal site selection by integrating fuzzy logic, AHP, and WLC in a GIS	2016	Fuzzy logic, AHP, WLC, GIS	The research describes a geographic information system-based, multi-criteria site selection method for an olive oil mill wastewater (OMW) disposal site in Tunisia's Sidi Bouzid Region.
[20]	Location Optimization of Wastewater Treatment Plants Using GIS: A Case Study in Umm Durman/Karary	2012	GIS, RS	The Nile River basin is one of Sudan's most significant water basins, used for household, agricultural, and industrial reasons, as well as energy generation, and it must be preserved. However, there are very few wastewater treatment plants in the basin, and they are required to safeguard the basin against contamination. This study focuses on GIS-based plant siting.
[21]	GIS-based optimization for the locations of sewage treatment plants and sewage outfalls – A case study of Nansha District in Guangzhou City, China	2009	GIS	This article uses GIS technology and the eco-suitability assessment approach, which incorporates economic, social, and ecological variables, to optimize the sites of sewage treatment facilities and outfalls. The investigation was motivated by the high level of environmental degradation caused by sewage water.
[22]	Suitable Site Selection of Decentralised Treatment Plants Using Multicriteria Approach in GIS	2012	AHP, GIS	One of the issues that develop when the city grows is the water supply and sewage treatment infrastructure.

Table A.0.4 (continued): Literature Review Summary of Site Selection for WWTP.

[23]	A Location Selection Method for Wastewater Treatment Plants Integrating Dynamic Change of Water Ecosystem and Socio-Cultural Indicators: A Case Study of Phnom Penh	2022	GIS, RS, AHP	Water pollution prevention relies heavily on the rational and effective location of wastewater treatment plants. This paper proposes a mechanism based on RS/GIS data to determine acceptable locations.
[24]	Using GIS and Fuzzy Logic for Wastewater Treatment Processes Site Selection: The Case of Rodopi Prefecture	2007	GIS, Fuzzy AHP	The study underlines the relevance of wastewater treatment plant site selection for sustainable natural resource utilization and economic growth. As a result, the research location was chosen from the northeast of Greece.
[25]	Geospatial Based Optimum Site Selection for Wastewater Treatment Plant: The Case of Debre Berhan Town, Amhara Regional State, Ethiopia	2019	GIS, AHP	In the city of Debre Berhan (Africa), wastewater is released onto highways, open spaces, and waterways that have not been recognized by any scientific investigation. The purpose of this research is to identify the facility's location to prevent environmental contamination.
[26]	Optimal location of artificial recharge of treated wastewater using fuzzy logic approach	2017	GIS, Fuzzy Logic	Increased water demand considering restricted water resources has escalated groundwater consumption and extraction, while also increasing wastewater generation. As a result, the study's goal is to determine the optimal site for wastewater treatment plants.

Table A.0.5 (continued): Literature Review Summary of Site Selection for WWTP.

[27]	A multi-criteria GIS model for suitability analysis of locations of decentralized wastewater treatment units: case study in Sulaimania, Iraq	2019	GIS, AHP	Sulaymaniyah, a city in northern Iraq, is experiencing a water scarcity, which may worsen if no action is taken. Some potential options include using treated wastewater for irrigation, washing, firefighting, groundwater replenishment, and so on; however, the city lacks a wastewater treatment plant. The study intends to address this issue.
[28]	Selection of Wastewater Treatment Plant Site for Bahir Dar Town, Ethiopia Using Multi-Criteria Analysis on GIS platform	2021	GIS, AHP	The study's goal is to use GIS-based MCDM techniques to determine the most environmentally and economically feasible location for the wastewater treatment facility in Bahir Dar town. Approximately two-thirds of houses in Bahir Dar discharge wastewater into waterways. They also dump their effluent into Lake Tana and the Abbay River (Blue Nile) via pipelines and open ditches.
[29]	GIS application for urban domestic wastewater treatment site selection in the Northern Ethiopia, Tigray Regional State: a case study in Mekelle City	2020	GIS, AHP, WSP (Waste Stabilization Pond Technology)	Despite being one of Ethiopia's fastest developing cities, Mekelle has inadequate wastewater treatment. Because the city lacks sufficient infrastructure for the collection and treatment of urban wastewater, effluent produced from various sectors immediately enters the city's urban drainage system and eventually flows into the Ellala River.

Table A.0.6 (continued): Literature Review Summary of Site Selection for WWTP.

[30]	Multi-Criteria Assessment Model to Identify Suitable Areas for Treated Wastewater Reuse in Agriculture	2021	GIS, Scenario analysis	Agriculture is one of the most vulnerable industries to the water issue since it consumes the most freshwater resources.
[31]	Evolution Site Selection by Using an Analytical Hierarchy Process for Decentralized Wastewater Treatment Plants in the City of Qom, Iran	2017	AHP	Wastewater treatment facilities are a critical method for developing nations, and site selection is a key element in their implementation. In this context, the purpose of this study is to conduct a site selection study in the city of Qom, Iran, in response to the growing demand for water resources and the increasing use of water in agriculture.
[32]	Analysis and Site Suitability Evaluation for Textile Sewage Water Treatment Plant in Salem Corporation, Tamilnadu Using Remote Sensing Techniques	2014	RS, GIS	Textile processing plants in Tamilnadu's Erode, Karur, Salem, and Tirupur districts create chemically harmful effluent, damaging subsoil, and surface waterways, particularly the Cauvery River. To avoid this, the study assessed the appropriateness of the wastewater treatment facility for the site selection study.
[34]	GIS-Based Multi Criteria Analysis for Optimal Sites Selection for a Sewage Treatment Plant - A case Study at Elamkulam, Kochi, Kerala	2021	GIS, RS (Weighted Overlay)	The aim of this research is to use GIS-based multi-criteria Analysis to identify the best locations for a wastewater treatment facility in Kochi's Elamkulam district.

Table A.0.7 (continued): Literature Review Summary of Site Selection for WWTP.

[35]	Use of Geospatial Technologies in the Selection of Suitable Sites for a Wastewater Treatment Plant	2018	AHP, GIS	Population development has resulted in water, soil, and air pollution in several metropolitan areas. In the research, WWTP sites were chosen to address current issues.

APPENDIX B

Table B.1: Sensitivity Analysis for Slope (C1) Criteria.

	Weights	%0	%20	%40	%60	%80	%100
C1	0.0998	0.0000	0.2000	0.4000	0.6000	0.8000	1.0000
C2	0.1680	0.1856	0.1503	0.1150	0.0797	0.0343	0.0000
C3	0.1021	0.1086	0.0956	0.0825	0.0695	0.0527	0.0000
C4	0.0835	0.0879	0.0791	0.0704	0.0617	0.0505	0.0000
C5	0.2580	0.2995	0.2163	0.1330	0.0498	0.0000	0.0000
C6	0.1995	0.2243	0.1746	0.1248	0.0750	0.0110	0.0000
C7	0.0891	0.0941	0.0841	0.0742	0.0643	0.0515	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table B.2: Sensitivity Analysis for Elevation (C2) Criteria.

	Weights	%0	%20	%40	%60	%80	%100
C1	0.0998	0.0998	0.1116	0.0976	0.0835	0.0694	0.0502
C2	0.1680	0.0000	0.2000	0.4000	0.6000	0.8000	1.0000
C3	0.1021	0.1145	0.0997	0.0850	0.0703	0.0502	0.0000
C4	0.0835	0.0918	0.0819	0.0721	0.0622	0.0488	0.0000
C5	0.2580	0.3369	0.2430	0.1490	0.0550	0.0000	0.0000
C6	0.1995	0.2467	0.1905	0.1343	0.0781	0.0013	0.0000
C7	0.0891	0.0985	0.0873	0.0761	0.0649	0.0496	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table B.3: Sensitivity Analysis for Distance from Road Network (C3) Criteria.

	Weights	%0	%20	%40	%60	%80	%100
C1	0.0998	0.1062	0.0937	0.0812	0.0687	0.0526	0.0000
C2	0.1680	0.1861	0.1507	0.1153	0.0799	0.0343	0.0000
C3	0.1021	0.0000	0.2000	0.4000	0.6000	0.8000	1.0000
C4	0.0835	0.0880	0.0792	0.0705	0.0617	0.0505	0.0000
C5	0.2580	0.3006	0.2171	0.1336	0.0502	0.0000	0.0000
C6	0.1995	0.2250	0.1751	0.1251	0.0752	0.0110	0.0000
C7	0.0891	0.0942	0.0842	0.0743	0.0643	0.0515	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table B.4: Sensitivity Analysis for Land Use / Land Cover (C4) Criteria.

	Weights	%0	%20	%40	%60	%80	%100
C1	0.0998	0.1049	0.0927	0.0804	0.0682	0.0524	0.0000
C2	0.1680	0.1825	0.1478	0.1132	0.0785	0.0337	0.0000
C3	0.1021	0.1074	0.0946	0.0818	0.0691	0.0525	0.0000
C4	0.0835	0.0000	0.2000	0.4000	0.6000	0.8000	1.0000
C5	0.2580	0.2921	0.2104	0.1287	0.0470	0.0000	0.0000
C6	0.1995	0.2199	0.1710	0.1222	0.0733	0.0101	0.0000
C7	0.0891	0.0932	0.0834	0.0737	0.0639	0.0513	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table B.5: Sensitivity Analysis for Distance from Water Bodies (C5) Criteria.

	Weights	%0	%20	%40	%60	%80	%100
C1	0.0998	0.1247	0.1054	0.0861	0.0668	0.0461	0.0000
C2	0.1680	0.2385	0.1838	0.1292	0.0746	0.0158	0.0000
C3	0.1021	0.1281	0.1080	0.0878	0.0676	0.0459	0.0000
C4	0.0835	0.1009	0.0874	0.0739	0.0604	0.0459	0.0000
C5	0.2580	0.0000	0.2000	0.4000	0.6000	0.8000	1.0000
C6	0.1995	0.2989	0.2218	0.1448	0.0678	0.0000	0.0000
C7	0.0891	0.1089	0.0936	0.0782	0.0628	0.0463	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table B.6: Sensitivity Analysis for Distance from Settlements (C6) Criteria.

	Weights	%0	%20	%40	%60	%80	%100
C1	0.0998	0.1151	0.0998	0.0844	0.0691	0.0461	0.0000
C2	0.1680	0.2113	0.1679	0.1245	0.0811	0.0158	0.0000
C3	0.1021	0.1181	0.1021	0.0860	0.0700	0.0459	0.0000
C4	0.0835	0.0942	0.0835	0.0728	0.0620	0.0459	0.0000
C5	0.2580	0.3601	0.2577	0.1554	0.0531	0.0000	0.0000
C6	0.1995	0.0000	0.2000	0.4000	0.6000	0.8000	1.0000
C7	0.0891	0.1013	0.0891	0.0769	0.0647	0.0463	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table B.7: Sensitivity Analysis for Soil Type (C7) Criteria.

	Weights	%0	%20	%40	%60	%80	%100
C1	0.0998	0.1053	0.0930	0.0807	0.0684	0.0525	0.0000
C2	0.1680	0.1835	0.1487	0.1138	0.0790	0.0340	0.0000
C3	0.1021	0.1078	0.0950	0.0821	0.0692	0.0526	0.0000
C4	0.0835	0.0873	0.0787	0.0701	0.0615	0.0504	0.0000
C5	0.2580	0.2946	0.2124	0.1302	0.0480	0.0000	0.0000
C6	0.1995	0.2214	0.1722	0.1231	0.0739	0.0105	0.0000
C7	0.0891	0.0000	0.2000	0.4000	0.6000	0.8000	1.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

APPENDIX C

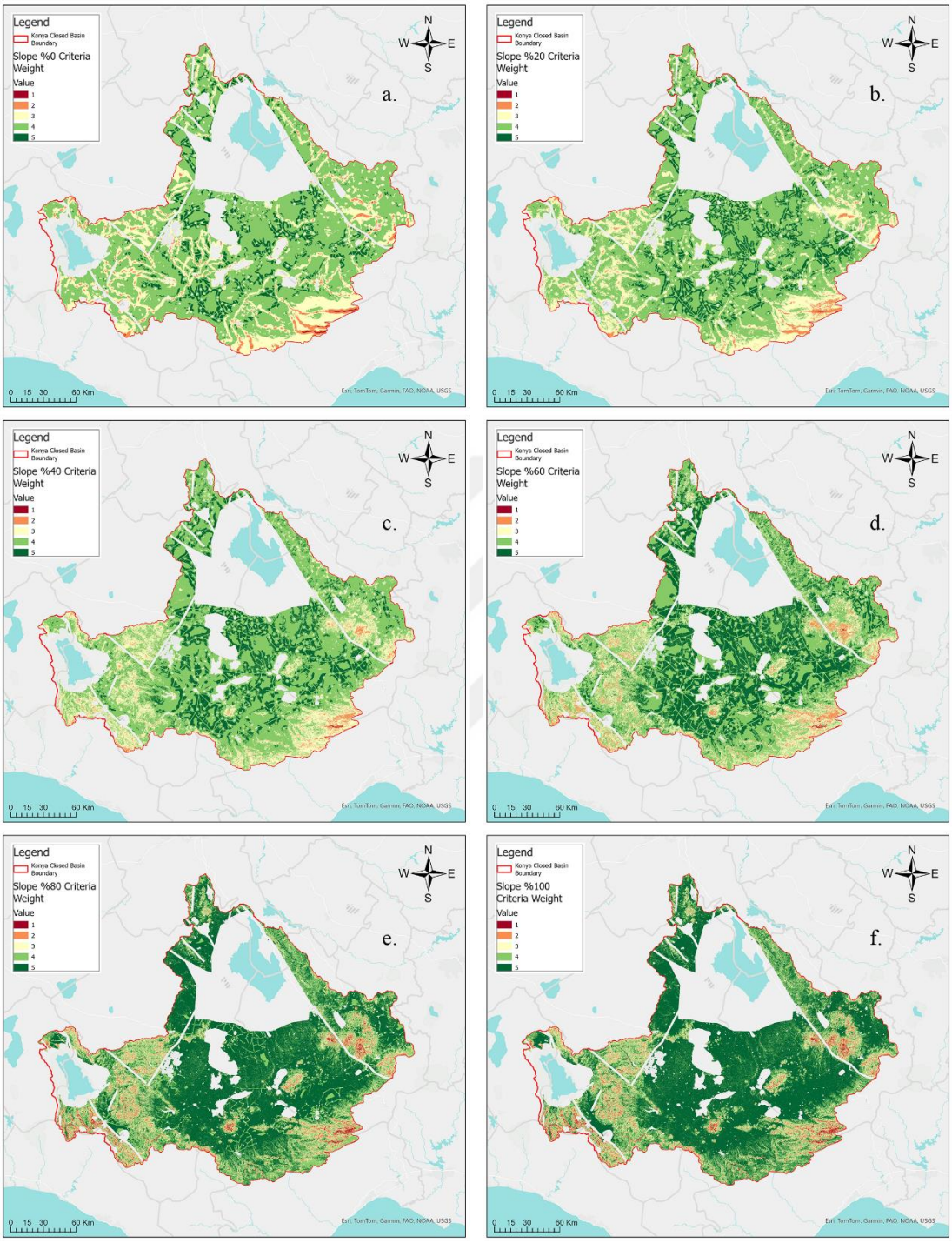

Figure C.1: Sensitivity analysis based on %0 criterion weight value for slope criteria (a), Sensitivity analysis based on %20 criterion weight value for slope criteria (b), Sensitivity analysis based on %40 criterion weight value for slope criteria (c), Sensitivity analysis based on %60 criterion weight value for slope criteria (d), Sensitivity analysis based on %80 criterion weight value for slope criteria (e), Sensitivity analysis based on %100 criterion weight value for slope criteria (f)

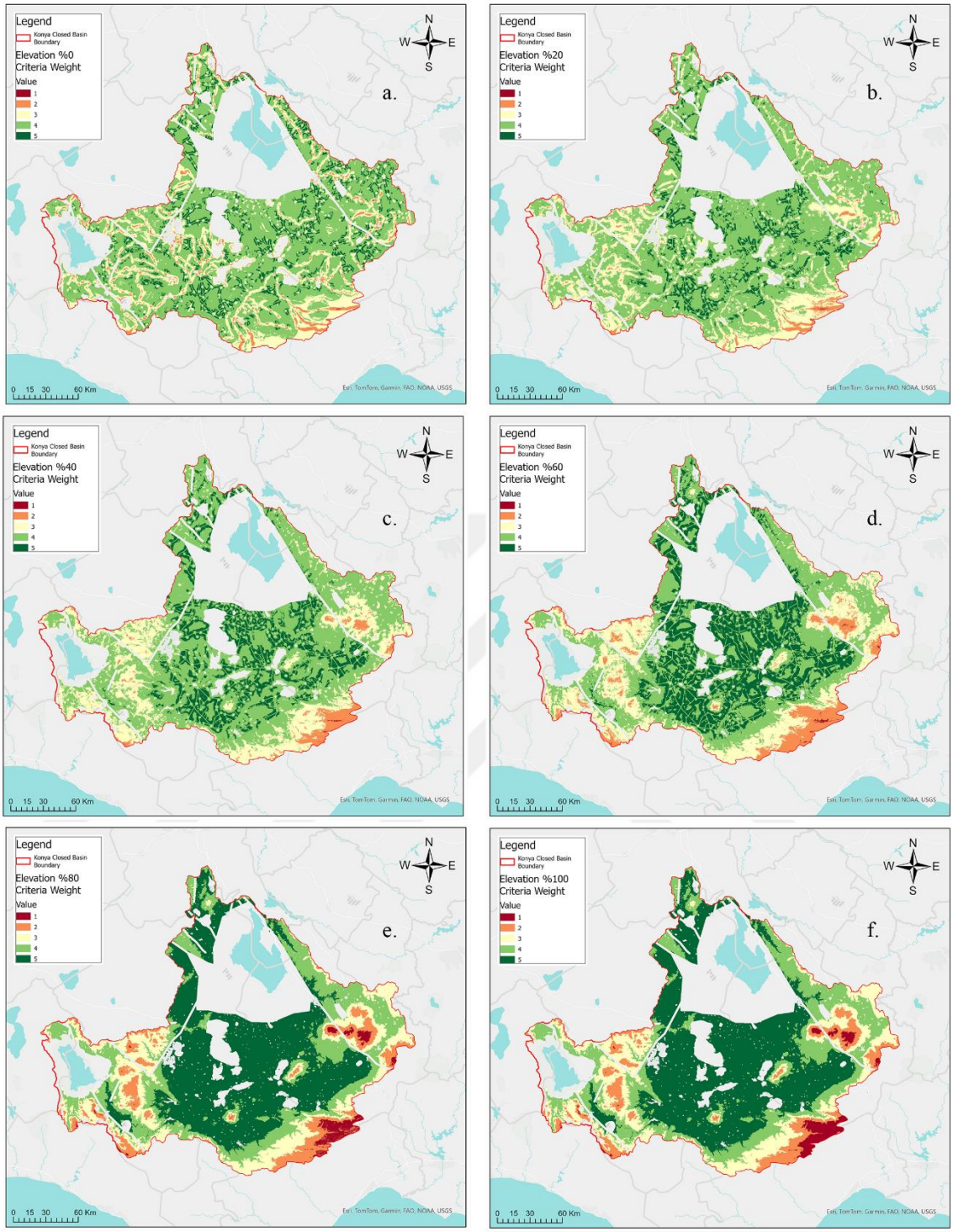

Figure C.2: Sensitivity analysis based on %0 criterion weight value for elevation criteria (a), Sensitivity analysis based on %20 criterion weight value for elevation criteria (b), Sensitivity analysis based on %40 criterion weight value for elevation criteria (c), Sensitivity analysis based on %60 criterion weight value for elevation criteria (d), Sensitivity analysis based on %80 criterion weight value for elevation criteria (e), Sensitivity analysis based on %100 criterion weight value for elevation criteria (f)

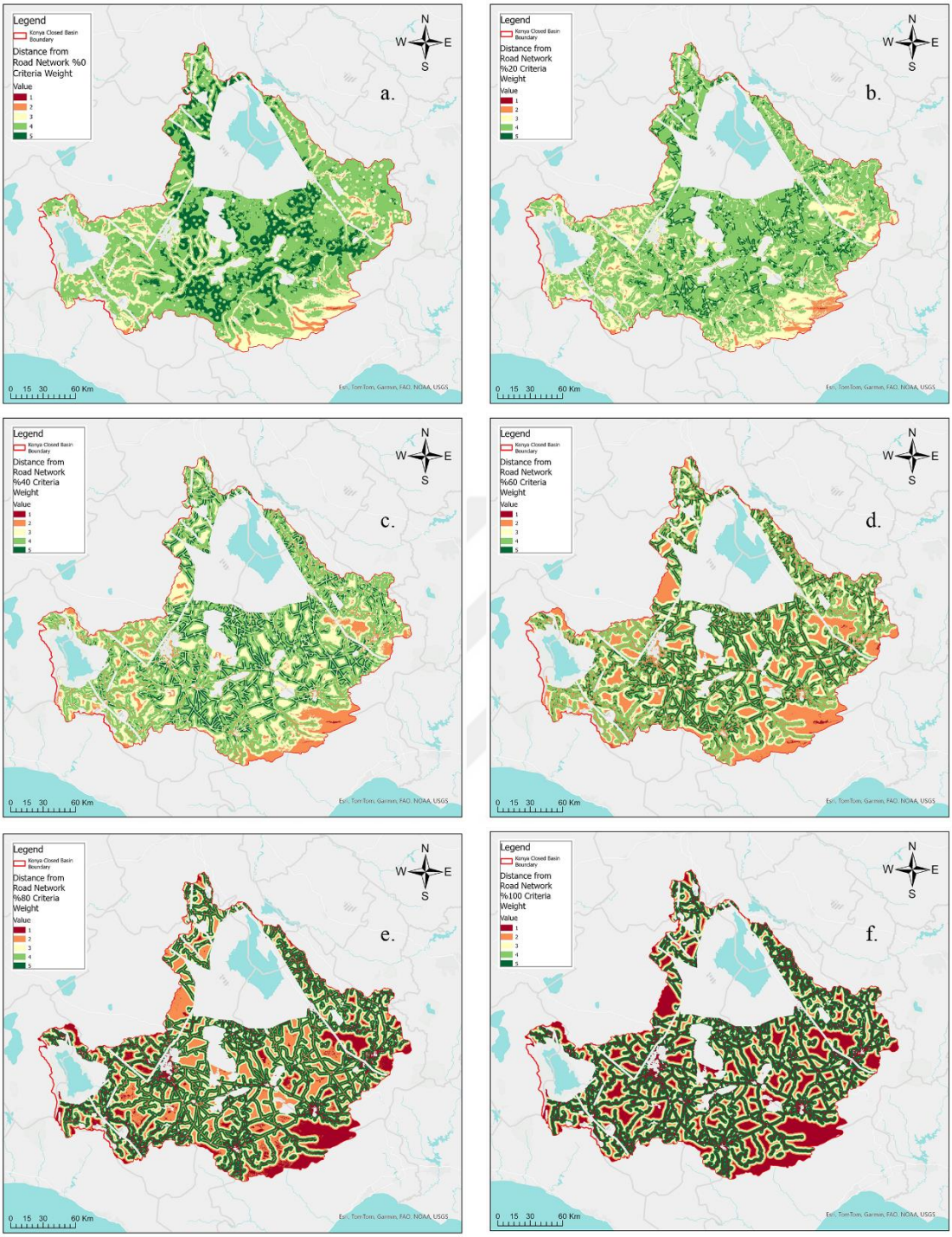

Figure C.3: Sensitivity analysis based on %0 criterion weight value for distance from road network criteria (a), Sensitivity analysis based on %20 criterion weight value for distance from road network criteria (b), Sensitivity analysis based on %40 criterion weight value for distance from road network criteria (c), Sensitivity analysis based on %60 criterion weight value for distance from road network criteria (d), Sensitivity analysis based on %80 criterion weight value for distance from road network criteria (e), Sensitivity analysis based on %100 criterion weight value for distance from road network criteria (f)

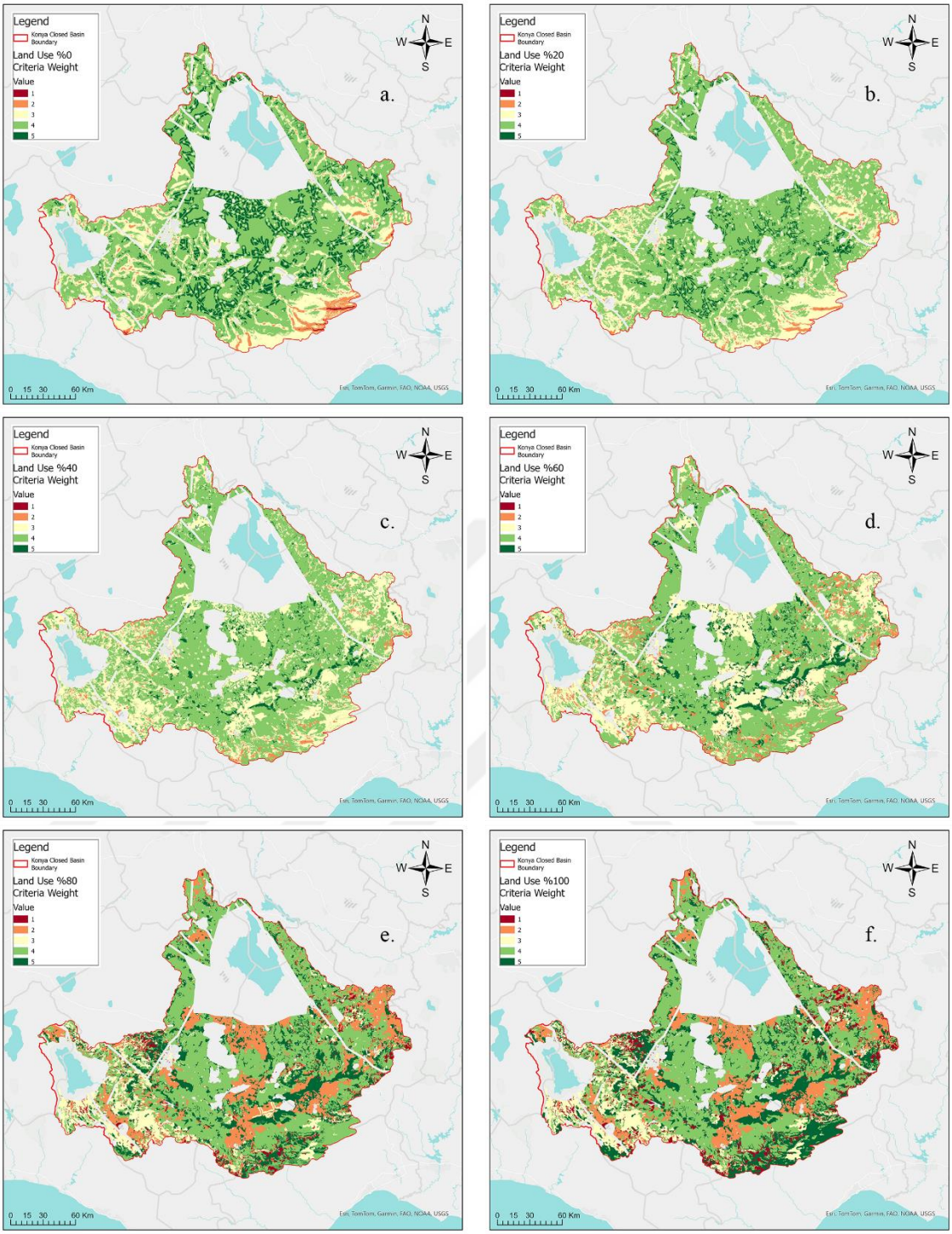

Figure C.4: Sensitivity analysis based on %0 criterion weight value for land use criteria (a), Sensitivity analysis based on %20 criterion weight value for land use criteria (b), Sensitivity analysis based on %40 criterion weight value for land use criteria (c), Sensitivity analysis based on %60 criterion weight value for land use criteria (d), Sensitivity analysis based on %80 criterion weight value for land use criteria (e), Sensitivity analysis based on %100 criterion weight value land use criteria (f)

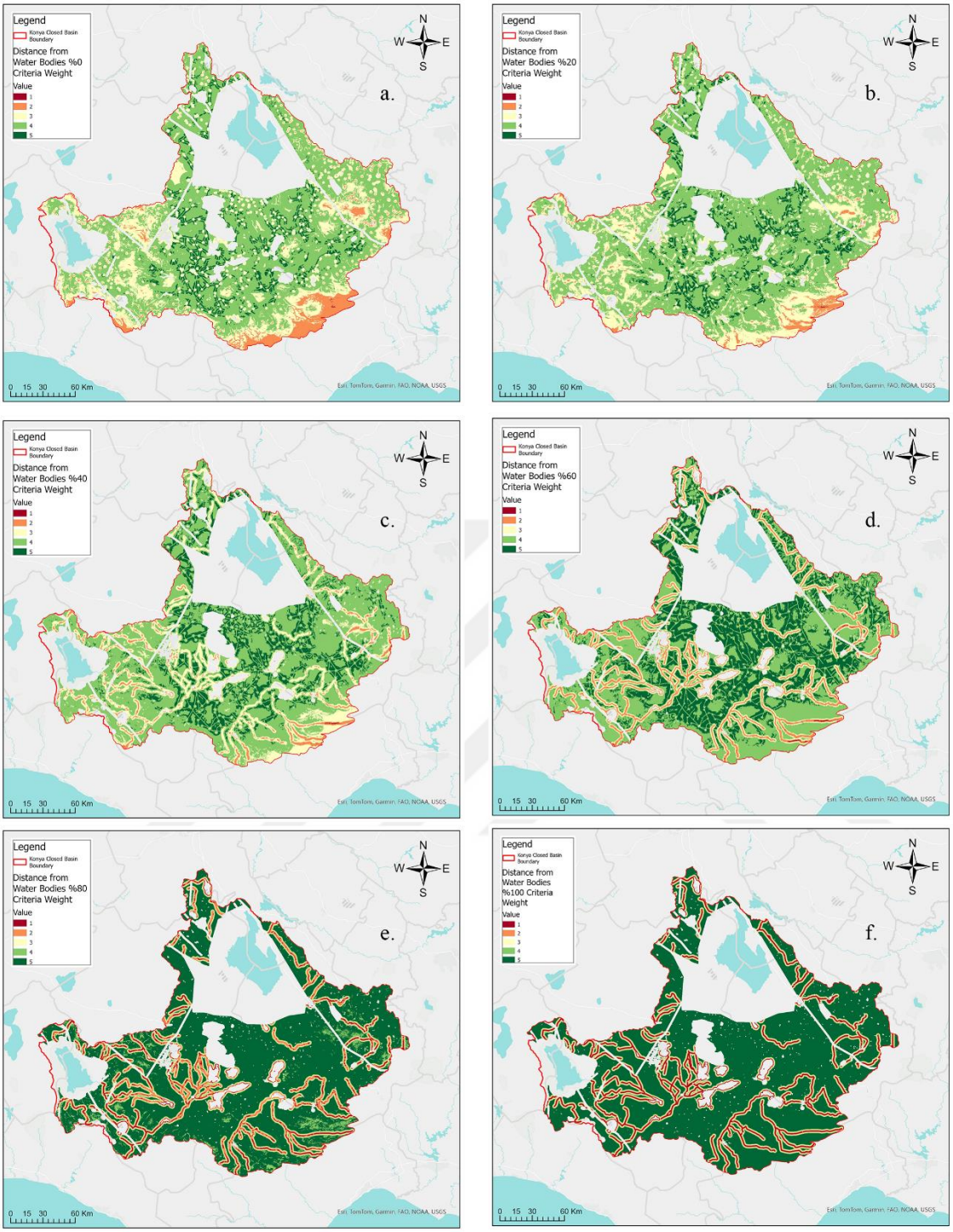

Figure C.5: Sensitivity analysis based on %0 criterion weight value for distance from water bodies criteria (a), Sensitivity analysis based on %20 criterion weight value for distance from water bodies criteria (b), Sensitivity analysis based on %40 criterion weight value for distance from water bodies criteria (c), Sensitivity analysis based on %60 criterion weight value for distance from water bodies criteria (d), Sensitivity analysis based on %80 criterion weight value for distance from water bodies criteria (e), Sensitivity analysis based on %100 criterion weight value for distance from water bodies criteria (f)

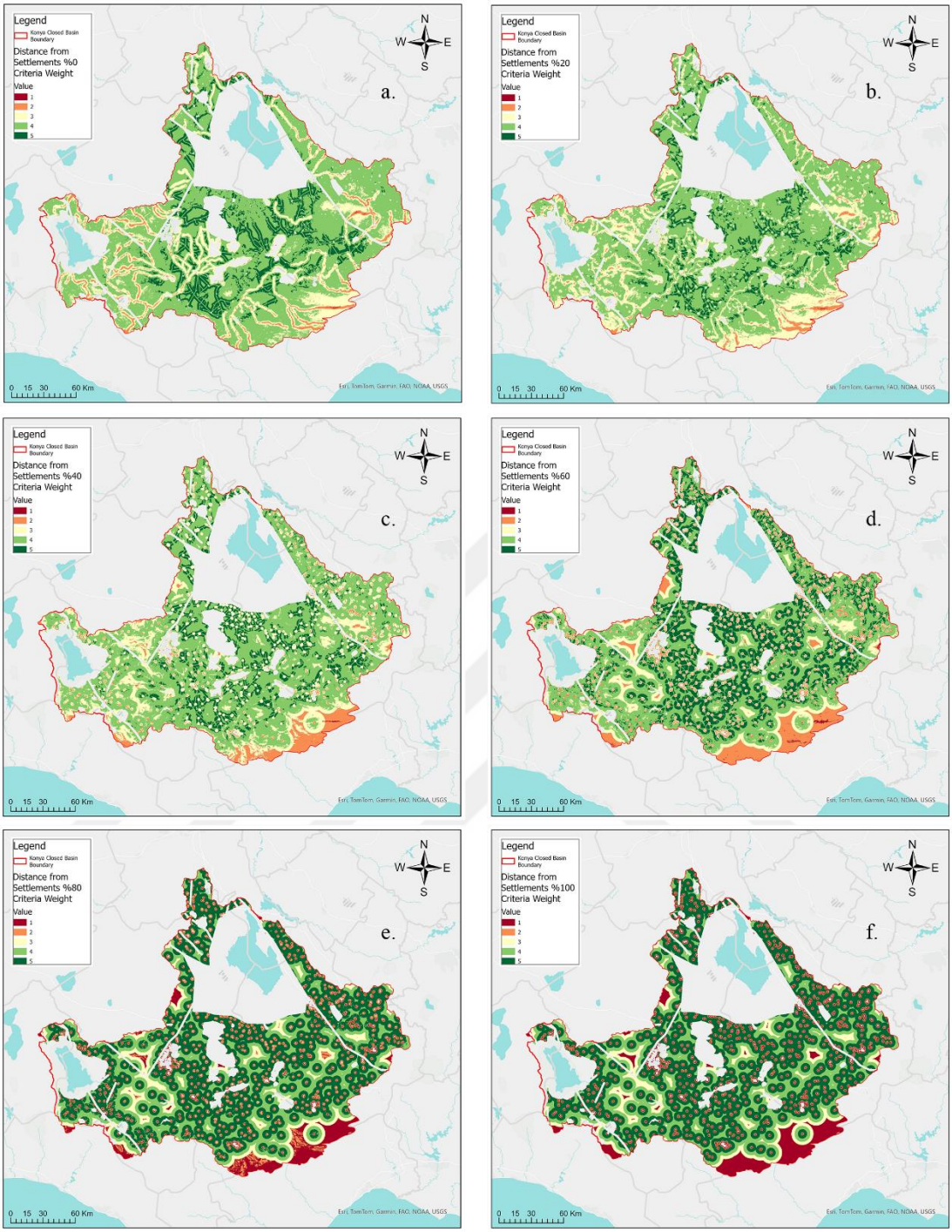

Figure C.6: Sensitivity analysis based on %0 criterion weight value for distance from settlements criteria (a), Sensitivity analysis based on %20 criterion weight value for distance from settlements criteria (b), Sensitivity analysis based on %40 criterion weight value for distance from settlements criteria (c), Sensitivity analysis based on %60 criterion weight value for distance from settlements criteria (d), Sensitivity analysis based on %80 criterion weight value for distance from settlements criteria (e), Sensitivity analysis based on %100 criterion weight value for distance from settlements criteria (f)

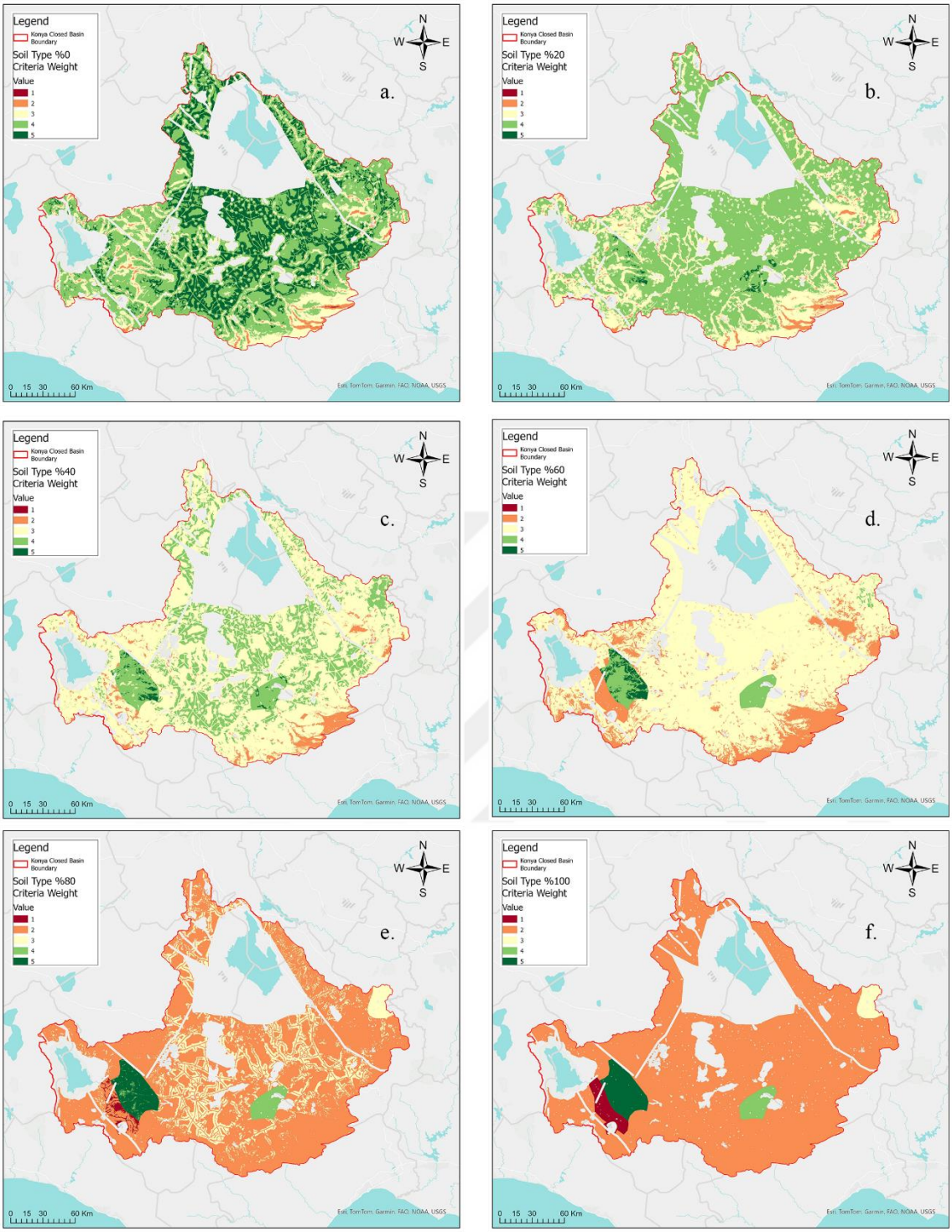

Figure C.7: Sensitivity analysis based on %0 criterion weight value for soil type criteria (a), Sensitivity analysis based on %20 criterion weight value for soil type criteria (b), Sensitivity analysis based on %40 criterion weight value for soil type criteria (c), Sensitivity analysis based on %60 criterion weight value for soil type criteria (d), Sensitivity analysis based on %80 criterion weight value for soil type criteria (e), Sensitivity analysis based on %100 criterion weight value for soil type criteria (f)

ÖZGEÇMİŞ

Ad-Soyad : Elif Çelikel

ÖĞRENİM DURUMU:

- **Lisans :** 2020, Yıldız Teknik Üniversitesi, Mimarlık Fakültesi, Şehir ve Bölge Planlam Bölümü
- **Yükseklisans :** 2024, İstanbul Teknik Üniversitesi, Bilişim Uygulamaları Anabilim Dalı, Coğrafi Bilgi Teknolojileri Programı

MESLEKİ DENEYİM VE ÖDÜLLER:

- **Esri Türkiye :** Ocak 2023 - , Çözüm Mühendisi

YÜKSEKLİSANS TEZİNDEN TÜRETİLEN YAYINLAR, SUNUMLAR VE PATENTLER:

- **Çelikel E.**, Erden T. 2024. GIS and Best-Worst Method Integration for Wastewater Treatment Plant Site Selection. 3rd International Graduate Research Symposium, May 8-10, 2024 İstanbul, Türkiye.