2016-06

A spatial analysis and game theoretical approach over the disputed islands in the Aegean Sea

Salin, Samet A.

Monterey, California: Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

A SPATIAL ANALYSIS AND GAME THEORETICAL APPROACH OVER THE DISPUTED ISLANDS IN THE AEGEAN SEA

by

Samet A. Salin

June 2016

Thesis Advisor: Kyle Y. Lin
Second Reader: Lyn R. Whitaker

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704–0188*

1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** June 2016	**3. REPORT TYPE AND DATES COVERED** Master's thesis

4. TITLE AND SUBTITLE A SPATIAL ANALYSIS AND GAME THEORETICAL APPROACH OVER THE DISPUTED ISLANDS IN THE AEGEAN SEA	**5. FUNDING NUMBERS**
6. AUTHOR(S) Samet A. Salin	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A	**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number ____N/A____.

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited	**12b. DISTRIBUTION CODE** A

13. ABSTRACT (maximum 200 words)

Throughout history, the Aegean Sea has been a sea of crisis. Today, Turkey and Greece—the two countries surrounding the Aegean Sea—continue to dispute several issues regarding the Aegean. The most significant dispute is over the sovereignty of several islands. This research presents a method to produce an arbitration solution to allocate these disputed islands between the two countries. We identify 39 disputed islands and six important attributes for each island, including perimeter, area, population, distance to Greece, distance to Turkey, and territorial water area. After applying spatial analysis to two open-source maps, we apply utility theory, the Analytical Hierarchy Process, and the Nash arbitration scheme to propose an arbitration solution. The arbitration solution tends to allocate to Turkey those islands with larger areas of territorial waters and greater proximity to the Turkish mainland, and allocate to Greece those islands with larger population and greater proximity to the Greek mainland.

14. SUBJECT TERMS spatial analysis, game theory, Nash arbitration scheme, Aegean, disputed islands, territorial waters, utilization, Turkey, Greece, bargaining problem, analytical hierarchy process	**15. NUMBER OF PAGES** 73
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UU

NSN 7540–01-280-5500 Standard Form 298 (Rev. 2–89) Prescribed by ANSI Std. 239–18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

A SPATIAL ANALYSIS AND GAME THEORETICAL APPROACH OVER THE DISPUTED ISLANDS IN THE AEGEAN SEA

Samet A. Salin
Lieutenant Junior Grade, Turkish Naval Forces
B.S., Turkish Naval Academy, 2010

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
June 2016

Approved by: Kyle Y. Lin
Thesis Advisor

Lyn R. Whitaker
Second Reader

Patricia Jacobs
Chair, Department of Operations Research

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

Throughout history, the Aegean Sea has been a sea of crisis. Today, Turkey and Greece—the two countries surrounding the Aegean Sea—continue to dispute several issues regarding the Aegean. The most significant dispute is over the sovereignty of several islands. This research presents a method to produce an arbitration solution to allocate these disputed islands between the two countries. We identify 39 disputed islands and six important attributes for each island, including perimeter, area, population, distance to Greece, distance to Turkey, and territorial water area. After applying spatial analysis to two open-source maps, we apply utility theory, the Analytical Hierarchy Process, and the Nash arbitration scheme to propose an arbitration solution. The arbitration solution tends to allocate to Turkey those islands with larger areas of territorial waters and greater proximity to the Turkish mainland, and allocate to Greece those islands with larger population and greater proximity to the Greek mainland.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

AHP	Analytical Hierarchy Process
FIR	Flight Information Region
GIS	Geographic Information System
UNCLOS	United Nations Convention of the Law of the Sea
UNHCR	United Nations High Commissioner for Refugees
WGS	World Geodetic System

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

Throughout history, the Aegean Sea has been a ground for many conflicts. The Aegean Sea is surrounded by two states today, Turkey and Greece. During the 20th century, the tensions between these two countries increased several times due to several issues regarding the Aegean Sea. Among these issues, the dispute over the sovereignty of the "Gray Zone Islands" comes forth as the basic conflict between the two countries. This thesis proposes an approach to reconcile this dispute. The approach consists of three steps: (1) apply spatial analysis to obtain geographical parameters for these disputed islands; (2) use utility theory and the Analytical Hierarchy Process (AHP) to score each island for each country; and (3) apply the Nash arbitration scheme to partition the disputed islands impartially between the two countries.

In the first step, we identify 39 disputed islands and six parameters for these islands, including perimeter, area, population, distance to Greece, distance to Turkey, and territorial water area. To obtain these geographical parameters, we use ArcMap 10.3 to process two open-source maps, and use a statistical package, R, to create our dataset. These six parameters for each island form the basis for an arbitration solution.

In the second step, we convert the values of each parameter into utilities between 0 and 1 via utility curves. We then use AHP—a method that relies on pairwise comparison between parameters to weight the importance of each parameter—to compute a composite utility value for each island by a weighted average of individual parameter utilities.

In the third step, we frame the dispute over these islands as a two-person nonzero-sum game, and use the Nash arbitration scheme to partition the disputed islands equitably between the two players, Turkey and Greece. To use the Nash arbitration scheme, we assume that if either player refuses the arbitration solution, then neither country will get any of these disputed islands.

Since Turkey advocates a six nautical mile extension of territorial waters, while Greece advocates 12 nautical miles, we solve this model twice. In the case of the six

nautical mile extension, the Nash arbitration solution assigns 22 of the disputed islands to Turkey and the other 17 to Greece. In the case of the 12 nautical mile extension, the solution assigns 24 islands to Turkey and the other 15 to Greece. In both cases, the islands that are closer to the Turkish mainland and have a larger area of territorial waters tend to be ceded to Turkey, and the islands that have a larger population and are closer to the Greek mainland tend to be ceded to Greece. Increasing the territorial waters from six nautical miles to 12 nautical miles has a minor impact on the arbitration solution.

There are several ways to extend our work. First, we can add other parameters into our model, such as the natural resources on each island and merchant shipping intensity within the territorial waters of each island. Second, when assessing the utilities and applying AHP, government officials or scholars at research institutions may be able to provide a more objective assessment. Finally, our proposed approach can be applied to other conflicted (or non-conflicted) regions, such as the disputed islands in the South China Sea.

ACKNOWLEDGMENTS

During my education in NPS, I found many opportunities to develop myself not only in an academic way, but also in a professional and personal way. The strong friendships I have gained and the experiences I have been through are invaluable. Hence, I would like to express my gratitude to all the Turkish citizens whose taxes provided my education here.

I also want to express my deepest appreciations to my advisor, Professor Kyle Lin, for his unwavering patience and tremendous amount of help. I would also like to thank to my second reader, Professor Lyn Whitaker, for her diligent guidance and interest in the subject.

I am also thankful to Professor Alan Washburn and Professor Owen Guillermo for their support and input throughout the whole process.

Finally, I would like to express that I am greatly indebted to my parents for their most-sincere love and understanding. Miles away, I have always felt their presence and support with me.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

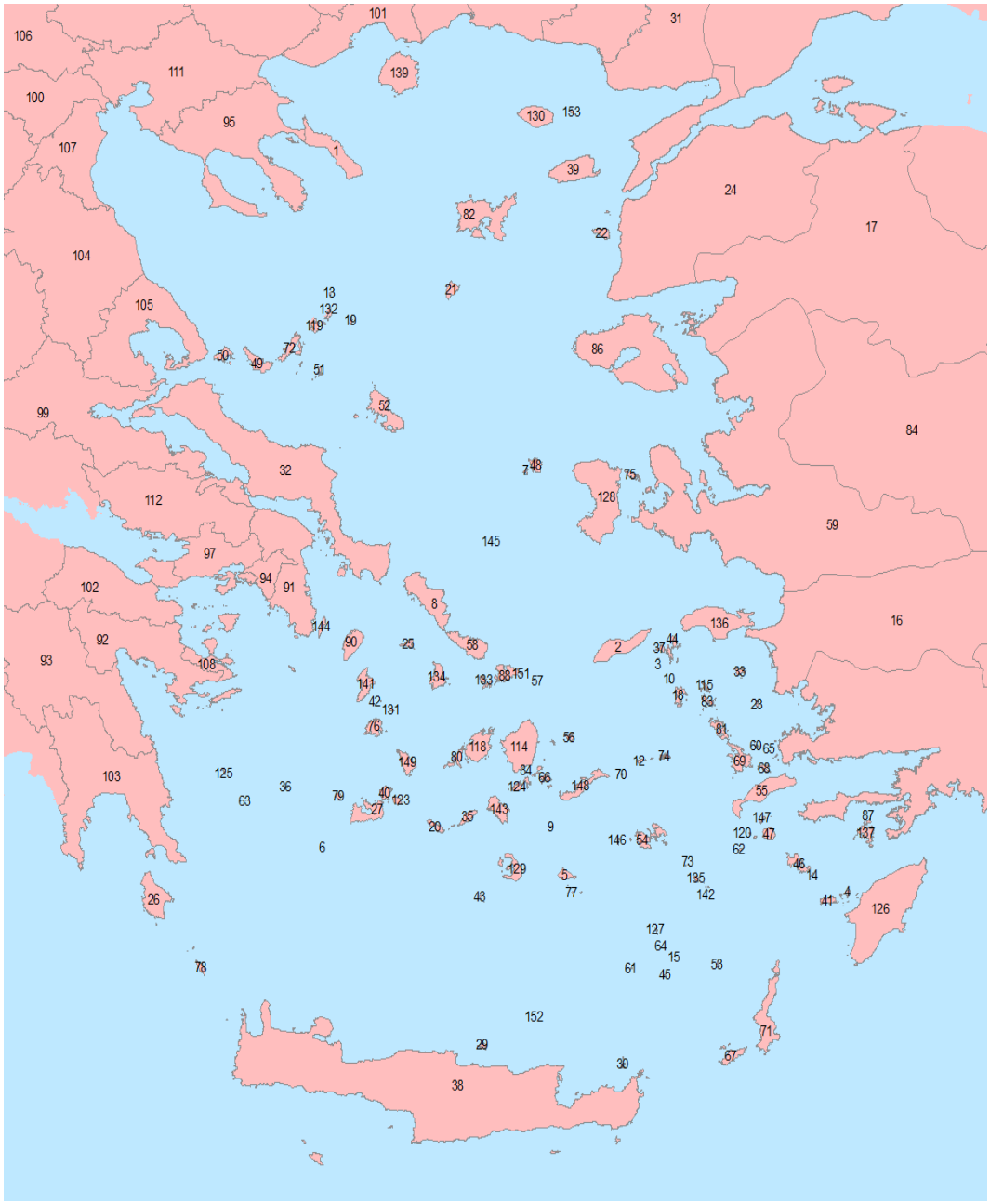
A. GENERAL INFORMATION ABOUT THE AEGEAN SEA

The Aegean Sea, also known as the Sea of the Islands, is located in the north of the Mediterranean Sea, between Asia and Europe. It covers an area that reaches from Western and Southern Anatolia to Greece, Macedonia, and Eastern Thrace. It holds a very important position providing one of the major trade routes between the Eastern and Western worlds. It is the only way to the Black Sea market via sea lanes and the only exit for Black Sea Navies to other seas. The islands are scattered all over the Aegean Sea, which provides geopolitical importance in consonance with their locations. The Aegean Sea is also important for its easy reach to the East and Central Mediterranean.

Throughout history, the Aegean Sea has been a ground for many conflicts based on its strategic advantages. Trojans, Ancient Greeks, Persians, Macedonians, Lydians, Ionians, Romans, Byzantines, Venetians, Ottomans, and many others have used this sea of plentiful resources for the wealth of their people and for expanding their influence over other regions. It is obvious that whomever controlled the Aegean Sea ruled over that geography during their times. Several reasons support this conclusion. Commercial superiority and transportation of people and/or vital goods like food, defensive materials, and troops are the key benefits of holding maritime superiority in the Aegean. Islands that are spread out across the sea enable long-lasting campaigns by providing naval bases and havens from foul weather, while operating as a replenishment points for merchant ships.

Today, the Aegean Sea is surrounded by two states, Turkey and Greece. It covers an area of about 214,000 km^2 between the Balkan and Anatolian Peninsulas (Ak, 2014a). According to some sources, it is assumed that there are over 1800 islands, islets and rocks of various sorts in the whole Aegean Sea. (For some of the major islands, see Figure 1; for island names, see the Appendix.)

Figure 1. The Aegean Sea.



Base maps sourced and adapted from “Tur_adm” and “Prefectures HEMCO.”

Most of the islands and islets belong to Greece, leaving Turkey a limited area of territorial waters and limiting the international waters in the Aegean. According to Mann (2001), Greece “thinks of the Aegean as (for the most part) a Greek Sea, and regards Turkey as following an aggressive policy that contests Greek sovereignty and sovereign

rights, as well as the legal status quo in the Aegean"; however, "Turkey, on the other hand, believes that the Aegean is a common entity that should be shared equally between the two countries and that both countries should respect each other's vital interests." Keeping these in mind, there are many issues between the two sides, as in the following.

- Territorial waters
- Continental shelf
- Flight Information Region (FIR)
- Militarization of the islands in demilitarized status
- Sovereignty of disputed islands (Gray Zone Islands)

During the 20th century, tensions between both countries have been strained by these issues. Furthermore, the two states came to the brink of war during the Kardak (Imia) Crisis in 1996 due to the dispute over sovereignty in the Aegean Sea.

After beginning with exploratory talks in 2002, both countries have continued trying to solve the disputed issues. However, new problems and developments have arisen, such as the crises of Syrian refugees seeking refuge in Europe via the Aegean Sea. Due to the emergence of the Islamic State in the Middle East, many refugees have left their homes hoping to find a new beginning and a safer life. According to the United Nations High Commissioner for Refugees (UNHCR) statistics, by July 2015, of the 4,013,000 Syrian refugees around the world, 1,805,255 are registered to seek asylum in Turkey. After the drowning of many refugees attempting to flee to the Greek Islands from Turkey, the Aegean Sea has become a huge humanitarian crisis.

The dispute over sovereignty of the "Gray Zone Islands" comes forth as the basic conflict between the two countries. The resolution of this conflict will provide a basis for overcoming the other major and minor issues in peaceful terms. Keeping that in mind, this thesis focuses on analyzing these "Gray Zone Islands" using spatial analysis tools, and applying game theoretical approaches to find a reconciliation basis between the two countries. It introduces the main disputes between the two countries in Chapter II, and discusses the spatial analysis over the geographical data according to the thesis of both countries about territorial waters in Chapter III. Chapter IV covers the utilization of the

islands and application of game theory, and Chapter V reflects our findings and recommendations.

B. HISTORICAL REVIEW OF THE PROBLEMS

From the beginning of the 20th century, the Aegean Sea has been a sea of crisis. Greece came about as an independent country in 1830 taking sovereignty over Eğriboz (Evvoia) Island and the Cyclades (Southwestern Aegean) Islands in addition to the Greek mainland. After the emergence of Greece, Greece extended her maritime territory in the Ionian and western Aegean Sea. In 1865, the Sporades Islands that are strategically very important to Greece mainland were ceded to Greece (Kurumahmut & Başeren, 2004).

In 1911, the Kingdom of Italy occupied Libya and the Tripolitania regions of the Ottoman Empire. During the course of the War of Tripolitania, Italy illicitly occupied the southeastern Aegean Islands, which are known today as the Menteşe (Dodecanese) Islands to force the Ottomans to negotiate for peace. Although these islands should have been handed over to Ottoman authorities, according to the Treaty of Ouchy (1912), the Italian government refused to turn over the islands with the excuse of the emerging Balkan War.

After the Turco-Italian War, during the 1912 Balkan War, Greece invaded the islands of Taşoz (Tasos), Semadirek (Samotraki), Gökçeada (Imros), Limni (Limnos), Bozcaada (Tenedos), Bozbaba (Evstratios), Midilli (Lesvos), Sakız (Thios), İpsara (Psara), Sisam (Samos) and Ahikerya (Ikaria) under Ottoman sovereignty (Kurumahmut & Başeren, 2004). After the Balkan Wars, during the London Conference in 1913, the Ottoman Empire accepted the terms of ceding the rights over the Girit (Crete) Island to Greece and arbitration of European Great Powers (Britain, France, Germany, Austria-Hungary, Italy and Russia) over all of the Ottoman islands in the Aegean Sea. In 1914, the verdict of the arbitration gave sovereignty over all islands except for Gökçeada (Imros), Bozcaada (Tenedos), and Meis (Castellorizo) to Greece under the condition of demilitarization (Ak, 2014b).

During the Lausanne Agreement in 1923, all of the islands except for Eğriboz Island, the North Sporades Islands, the Cyclades, Çuha, Küçük Çuha, and Crete, were

discussed and a new status quo in the Aegean Sea had been set. As Turkey's sovereignty over Gökçeada (Imros), Bozcaada (Tenedos), and the Tavşan Islands were confirmed by the treaty, the islands of Limni, Semadirek, Midilli, Sakız, Sisam, and Ahikerya stated by name were confirmed to be under Greek sovereignty (Kurumahmut & Başeren, 2004). Moreover, unless no verdict on the contrary was mentioned, all the islands within three miles of the Turkish coast were ceded to Turkey. Despite not being mentioned by name, the islands of Taşoz, Bozbaba, and İpsara were left to Greece from the verdict by arbitration by the six European Great Powers in 1914, since these islands were under Greek occupation after the Balkans War.

During the Lausanne Treaty (1923), Turkey agreed to renounce her rights of sovereignty for the 13 islands mentioned by name and their "dependent islets" and Meis (Castellorizo) in the region of the Menteşe (Dodecanese) Islands, which had been under Italian occupation since 1912 (in favor of Italy).

After losing to the Allies in World War II, Italy ceded sovereignty and all her rights over Meis and other Menteşe Islands mentioned by name, and their "adjacent islands," in favor of Greece with the condition that they be demilitarized (Van Dyke, 2005).

In December 1995, a Turkish merchant ship named Figen Agat grounded on the Kardak Rocks (Imia Islets) which consist of two uninhabited rocks (see Figure 2). Both Turkey and Greece claimed that the incident happened in their territorial waters and had the right to provide a rescue mission. This was the first time the sovereignty of the disputed islands was put forward by Turkey. Over the course of the events, Greek Special Forces landed on the east islet, and as a reaction to the Greeks landing, Turkish commandos landed on the west islet. Tensions escalated very quickly and both countries were on the brink of war. Turkish and Greek Navies were positioned around the islets for reconnaissance and further reactions if necessary. The tension de-escalated with the assistance of the United States without causing any military conflict.

Figure 2. Kardak/Imia Islands.

Image retrieved from Google Earth, May 20, 2015, https://www.google.com/earth/.

II. CONTEMPORARY AEGEAN SEA ISSUES BETWEEN TURKEY AND GREECE

A. TERRITORIAL WATERS

During the Treaty of Lausanne in 1923, both sides came to terms with each other over the three-mile extension of territorial waters in the Aegean Sea. In 1936, Greece extended her territorial waters to six miles unilaterally, finding no opposition from the Turkish side. When that happened, the status quo set in terms of territorial waters had degenerated in favor of Greece. In 1964, Turkey announced her extension to six miles, setting a new status quo in the Aegean Sea.

The 1982 United Nations Convention on the Law of the Sea (UNCLOS-III) states that "every state has the right to establish the breadth of its territorial sea up to a limit not exceeding 12 nautical miles" (Van Dyke, 2005). Due to a considerable extent to the provision, Turkey did not sign the UNCLOS-III. The other non-signatories were the United States, the United Kingdom, the Federal Republic of Germany, Israel, Ecuador, Venezuela, and Peru (Heraclides, 2010). Thus, Turkey rejected the Greek thesis over extension of territorial waters up to 12 nautical miles in the Aegean.

After UNCLOS-III in 1982, the Greek authorities put forward their intension to extend territorial waters up to 12 nautical miles. That action found a strong and dedicated opposition on the Turkish side. UNCLOS-III came into force in 1994, and in 1995, Greece announced a unilateral expansion of the territorial waters to 12 nautical miles. Turkey responded to that move, and as a counter action, announced that this Greek practice was a Casus Belli (an act or event that provokes or is used to justify war).

In 2010, Turkey deleted the 1996 Casus Belli policy over the Greek expansion of territorial waters to 12 miles from the National Security Policy Document as a goodwill gesture in the course of exploratory talks between Greece and Turkey. Since 2002, exploratory talks have been made between both sides. Today, a six-mile status quo has still been in force; however, Greek arguments about the issue have stayed basically the same.

1. Turkish Thesis

In the 1980s, Turkey claimed that the Greek expansion to six miles in 1936 was not as innocent as it seemed, and it was part of a hidden agenda to render the Aegean Sea a “Greek Lake” (Heraclides, 2010). The Turkish thesis is centered on the retention of the six-mile status quo.

First of all, Turkey is not obligated to accept the Greek enforcement because Turkey did not sign or ratify the convention. Secondly, the extension of territorial waters cannot be done unilaterally. Article 300 of the UNCLOS-III (1982c) convention states that, “States Parties shall fulfil in good faith the obligations assumed under this Convention and shall exercise the rights, jurisdiction and freedoms recognized in this Convention in a manner which would not constitute an abuse of right.” Based on this article, Turkey asserts that the practice of extension should fulfill Article 300 first, and a Greek expansion to 12 miles is a clear abuse of that article.

Another claim made by Turkey in reference to UNCLOS-III Article 122 and 123 (1982b), is that the Aegean Sea is a “semi-enclosed sea,” and the coordination and cooperation of countries are required in the exercise of rights to avoid any abuse of rights. Such an extension would prevent the implementation of Turkey’s rights and navigational freedom in the Aegean Sea. According to Heraclides (2010), with the existing six-mile status quo, Greece controls 43.68% of the Aegean Sea, while Turkey owns 7.5%, leaving 49% as international waters. The enforcement of 12 miles would change this scenario drastically, Heraclides continues, by allowing Greece to have 71.53% and limiting the open sea to only 19.71%. In the aftermath of the 12-mile extension, Turkey would be locked up in Anatolia with almost 3,000 miles of coastline in the Aegean Sea, and left with no passage to open sea (Heraclides, 2010). Turkey thus asserts that the consequences of such an expansion would be economically, culturally, and strategically devastating.

2. Greek Thesis

In general, there are two main Greek theses in regard to the 12-mile extension of territorial waters. The first Greek thesis is that the regulation of territorial waters in UNCLOS-III has become a conventional law and a norm, and Greece is rightfully able to extend the breadth to 12 miles.

The second Greek thesis claims that the expansion of territorial waters is a norm only binding the regulator state with domestic law regulations, and thus, Greece can act unilaterally in this sense. Regarding the Article 123 of UNCLOS-III, the Greek side expresses that this is not an obligatory rule, and hence, does not have to negotiate its terms. Therefore, Greece does not accept the existence of such disputes stating that it is decided merely by UNCLOS-III.

B. THE DISPUTED ISLANDS

During the Kardak Crisis in 1996, a new issue emerged between Turkey and Greece: sovereignty over some islands in the Aegean Sea. Some islands and islets were claimed by both countries, pushing bilateral relations to the edge in recent decades. Since the disputed islands constitute a sovereignty issue and the resolution would change the map of the Aegean Sea, especially in terms of territorial waters and the continental shelf, this appears to be the most important and basic conflict between the two countries. “Sovereignty disputes exist as a result of ambiguous language in the governing treaties listed [in the following paragraphs] and also because certain small islands were not mentioned by any treaty” and leaving some “matters in doubt” by the definition of some terms such as “adjacent” or “dependent” islands (Van Dyke, 2005).

The sovereignty issue has its roots in the first quarter of 20th century. During the Turco-Italo Libyan War in 1911–1912, Italy invaded the Menteşe (Dodacanese) Islands to force Turkey to accept her peace terms. With regard to the Treaty of Ouchy, Italian forces were supposed to be extracted after the extraction of Ottomanese forces from Libya. Meanwhile, in the Balkans, four states that acquired their independence from the Ottoman Empire in the last century, declared war upon the Ottomans. Italy took advantage of this new situation and using the Greek threat as an excuse, announced that

Italy would not withdraw from the islands. During the Balkans War, Greece invaded and took control of the islands of Taşoz (Tasos), Semadirek (Samotraki), Gökçeada (Imros), Limni (Limnos), Bozcaada (Tenedos), Bozbaba (Evstratios), Midilli (Lesvos), Sakız (Thios), İpsara (Psara), Sisam (Samos), and Ahikerya (Ikaria). Except for Gökçeada and Bozcaada, all the islands that were under Greek occupation were ceded to Greece according to the verdict of the arbitration by six European Great Powers (Ak, 2014b).

After the war between Greece and Turkey ended, and the Greek invasion of Western Anatolia failed in 1922, peace negotiations started in the city of Lausanne, Switzerland with the attendance of Turkey, Greece, the United Kingdom, France, Italy, Japan, Romania, the Serb-Croat-Slovene State (later Yugoslavia) ("Treaty of Peace," 1923). The United Soviet Socialist Republic (USSR) and Bulgaria also attended, but they only attended the sessions regarding the Turkish Straits. Articles 12, 15, and 16 of UNCLOS-III encompass the regulations over sovereginty of the islands in this treaty.

Article 12 regulates the islands ceded to Greece in the Eastern Aegean Sea stating that:

> other than the islands of Imbros, Tenedos and Rabbit Islands, particularly the islands of Lemnos, Samothrace, Mytilene, Chios, Samos and Nikaria, is confirmed, subject to the provisions of the present Treaty respecting the islands placed under the sovereignty of Italy which form the subject of Article 15. Except where a provision to the contrary is contained in the present Treaty, the islands situated at less than three miles from the Asiatic coast remain under Turkish sovereignty. ("Treaty of Peace," 1923)

Article 15 of the Lausanne Treaty, which regards the Italian-occupied Menteşe Islands, states that "Turkey renounces in favour of Italy all rights and title over the following islands: Stampalia (Astrapalia), Rhodes (Rhodos), Calki (Kharki), Scarpanto, Casos (Casso), Piscopis (Tilos), Misiros (Nisyros), Calimnos (Kalymnos), Leros, Patmos, Lipsos (Lipso), Simi (Symi), and Cos (Kos), which are now occupied by Italy, and the islets dependent thereon, and also over the island of Castellorizzo" ("Treaty of Peace," 1923).

Finally, in Article 16, it is stated that:

> Turkey hereby renounces all rights and title whatsoever over or respecting the territories situated outside the frontiers laid down in the present Treaty and the islands other than those over which her sovereignty is recognised by the said Treaty, the future of these territories and islands being settled or to be settled by the parties concerned. The provisions of the present Article do not prejudice any special arrangements arising from neighbourly relations which have been or may be concluded between Turkey and any limitrophe countries. ("Treaty of Peace," 1923)

After World War II, with the Paris Peace Treaty, Italy renounced her sovereignty and rights over the islands mentioned above in Article 15 of the Lausanne Treaty in favor of Greece.

Overall, although the islands that were ceded to Greece were worded by name in the treaties mentioned above, Greece claims other islands and islets are a part of this island sets, pointing out Article 16 of the Lausanne Treaty. However, in Turkey's view, this article does not mean a mass renunciation. Another issue is the definition of "dependent" or "adjacent" islands. There are no such definitions in terms of international law, which causes another point of conflict. Today each country has developed its own thesis over the sovereignty issue.

1. Turkish Thesis

The Turkish thesis is that the islands that were not mentioned by name were not ceded to any country. Since the Republic of Turkey is the successor state to the Ottoman Empire, these islands belong to Turkey (Heraclides, 2010).

Another assertion put forward by Turkey is that Article 16 of the Lausanne Treaty has not yielded an overall transfer of the islands to another country (Van Dyke, 2005). Hence, the islands not mentioned by the name in these treaties are under the sovereignty of Turkey.

Turkey also claims that there is no definition of "dependent" islands, and thus, interpretation of the term must be made not only in terms of historical, geographical, and geological factors, but also in terms of economic, social, and security aspects.

Furthermore, there are several islands for which there is no question of geographical "dependency," which were not ceded to any other country by name.

2. Greek Thesis

The Greek thesis is centered on Article 16 of the Lausanne Treaty and claims that Turkey had renounced all the sovereign rights to Italy and Greece outside of three miles (Heraclides, 2010). Another argument supporting the Greek thesis holds that the disputed islands are a part of the island group, and they are dependent or adjacent to other islands.

It is also claimed that the wording of the Lausanne Treaty limits the islands that were left to Italy and Turkey to those mentioned in the treaty, and the entire Aegean Islands, except these, were ceded to Greece (Van Dyke, 2005).

III. DATA COLLECTION AND SPATIAL ANALYSIS

In this chapter, we construct a dataset for the disputed islands in the Aegean Sea. First, we import two open-source maps into ArcMap 10.3, which allows us to represent islands as polygons (ArcGIS, 2015). Second, we import these polygons into R (R Core Team, 2014), and use several library packages to create our dataset. Our final dataset consists of six parameters for each disputed island: perimeter, area, population, distance to Greece, distance to Turkey, and the territorial water area. These six parameters form the basis for an arbitration solution in Chapter IV.

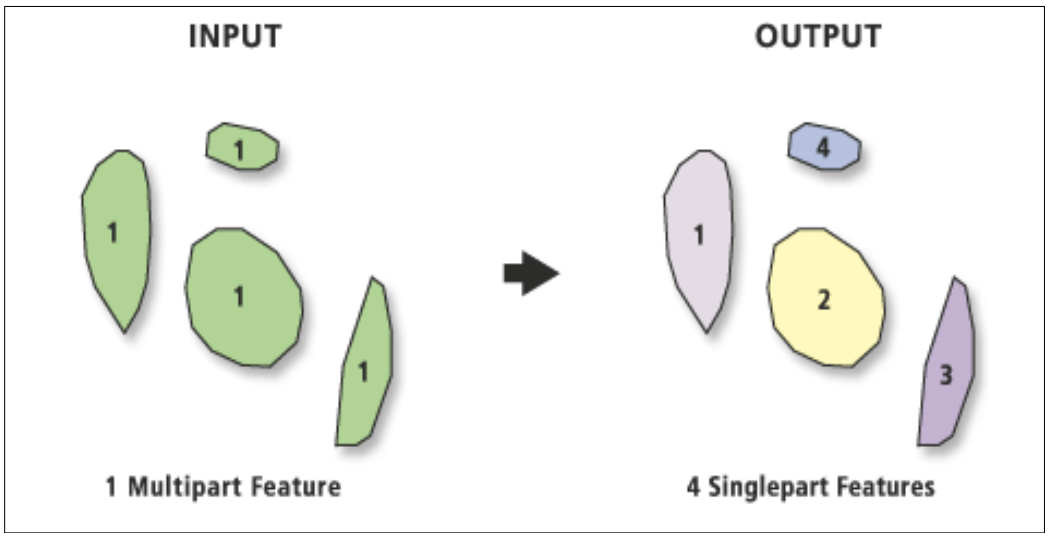
A. CREATING MAPS

In this study, we use ArcMAP 10.3 to create maps and separate islands into polygons. ArcMAP is a desktop application for Geographic Information System (GIS) professionals, and is a part of ArcGIS for Desktop.

We use two open-source maps: the Turkish Administrative Map ("Tur_adm," n.d) and the Greek Administrative Map ("Prefectures HEMCO," 2014). Both of these maps are available for download from the Internet. We merge these two maps to create one map for the disputed islands in the Aegean Sea.

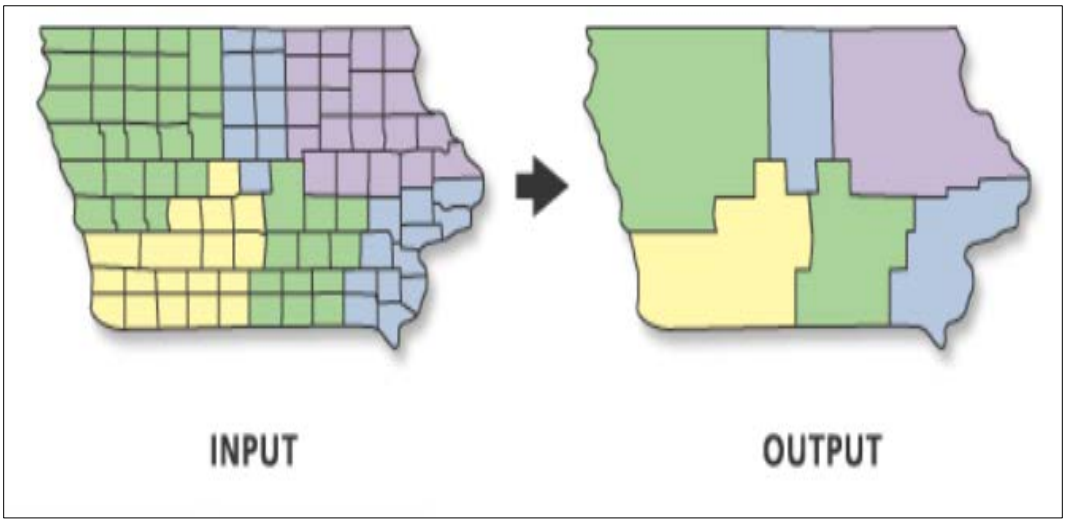
Our goal is to construct a list of disputed islands, and represent each island as a polygon for further data processing. The open-source maps, however, consist of polygon objects that represent a group of islands according to administrative municipalities. In some cases, a single polygon object includes more than 10 islands in the same administrative region. To construct a list of disputed islands, we first use a built-in function in ArcMap to break up a polygon object into several polygons, as shown in Figure 3.

Figure 3. Separation of polygons in ArcMAP. Source: ArcGIS (2015).



We then name the islands of interests and municipalities manually. After naming each polygon, we aggregate all the features based on the "name" attribute as an individual polygon, as shown in Figure 4.

Figure 4. Illustration of aggregation in ArcMap. Source: ArcGIS (2015).



After these operations, we construct a map of islands in the Aegean Sea colored according to sovereignty, as shown in Figure 5. The disputed islands are listed as in Kurumahmut & Başeren (2004), and additional information can be found online ("Aegean Dispute," n.d.). Although most islands are individually separated, some of them are close to each other, and most islands have adjacent rock formations or islets. In order to determine which islands or islets to include in our study, we need to take into consideration the location, size, and disputability of the islands. In the end, the dataset includes 39 disputed islands, which are shown in red and numbered in Figure 5. The names of these islands are listed in Table 1.

To calculate the various parameters of an island, such as the perimeter and the area, we use the World Geodetic System (WGS), whose latest version is designated as WGS-84. The polygon areas and perimeters are calculated automatically in consonance with WGS-84. Since WGS-84 was established in 1984 and last revised in 2004, there may be some small differences between the real area and perimeter of a territory and the calculated values. In this research, the values calculated via WGS-84 projection are taken up, and further analysis is conducted based on these values.

Table 1. List of 39 disputed islands.

ID	Turkish Names	Greek Names	ID	Turkish Names	Greek Names
1	ALATONISI	ALATONISI	21	KENDIROZ	LIADI
2	ANDIIPSARA	ANTIIPSARA	22	KIZKARDASLAR	ADELFOI
3	ANIDTRO	ANIDTRO	23	KOCBABA	LEVITHA
4	ARDICCIK	KINAROS	24	KOYUN ADALARI	OUINOUSSES
5	ASKINO	ANDITILOS	25	NERGISCIK	ARKI
6	AVGO	AVGO	26	PAKSIMADA	PAXIMADA
7	BULAMAC	FARMAKONISI	27	PAKYA	PACHEIA
8	DIA	DIA	28	PERGUSA	PERGUSA
9	DRAGONARA	DRAGONARA	29	PETROKARAVA	PETROKARAVA
10	ESEK	AGATHONISI	30	PLATI	PLATI
11	FORNOZ	FURNI	31	SAFRAN	SOFRANO
12	HURSID	FYMENA	32	SIRINA(ARDACIK)	SYRNA
13	IKI KARDASLAR	UNIANISIA	33	STROGGILI	STROGGILI
14	ISTAKIDA	ASTAKIDONISIA	34	UC ADALAR	PLAKIDHA
15	KALOLIMNI	KALOLIMNOS	35	VENEDIK	KALOGEROS
16	KAMILUN	CHAMILI	36	YALI	YIALI
17	KANDILLI	KANDELIOUSSA	37	YIANISADA	GIANISADA
18	KARAVO(KARABONEZ)	KARAVONISI	38	YUMURTA	AVGO LASITHOU
19	KARDAK	IMIA	39	ZURAFA	ZOURAFA
20	KECI	PSERIMOS	-	-	-

Figure 5. Aegean map colored according to sovereignty.

Base maps sourced and adapted from "Tur_adm" and "Prefectures HEMCO." The disputed islands are numbered according to the list in Table 1.

B. CONSTRUCTING THE DATASET

For each of the 39 disputed islands included in this study, we need to combine our spatial data with some other data. In our overall dataset, we have six parameters that yield a dataset with the dimensions 39 x 6:

1. Perimeter: Numeric value. Perimeter of the island (km). Values are pulled out via ArcMAP 10.3 as it is calculated via WGS-84.

2. Area: Numeric value. Area of the island itself (km^2). Values are pulled out via ArcMAP 10.3 as it is calculated via WGS-84.

3. Population: Numeric value. Population data of the islands based on 2011 census results are provided in a website (Brinkhoff, 2015). Only seven of the islands have a population.

4. Distance to Greece: Numeric value. Distance from Greek mainland or Crete (km), the shorter between the two. Distance from Crete is included since, the size of the island is significantly bigger than any other island in the region.

5. Distance to Turkey: Numeric value. Distance from Turkish mainland (km)

6. Territorial Water Area: Numeric value. Area of territorial waters of the island (km^2). Calculation of the territorial waters area is explained in Section C.

The first five parameters can be calculated in a straightforward manner, while the last parameter, namely the territorial water area, requires some effort. In Article 15 of UNCLOS-III, "delimitation of the territorial sea between states with opposite or adjacent coasts" are regulated, and the article articulates that:

> where the coasts of two states are opposite or adjacent to each other, neither of the two states is entitled, failing agreement between them to the contrary, to extend its territorial sea beyond the median line every point of which is equidistant from the nearest points on the baselines from which the breadth of the territorial seas of each of the two states is measured. (United Nations, 1982a)

According to this definition, all points within an intersected area of territorial waters should be equally distant to each state's nearest point on the baseline. Since the baseline is also a disputed issue, in our study, we assume that it is the nearest piece of land on the map.

Since Greece advocates that territorial waters may extend up to 12 miles, while Turkey advocates six miles, we study both of these scenarios separately. The most important and challenging part of our problem is to calculate the intersected areas, particularly if there are more than two intersected areas. To overcome this problem, Thiessen Polygons are used in our study to determine the median line between islands that have intersected territorial waters.

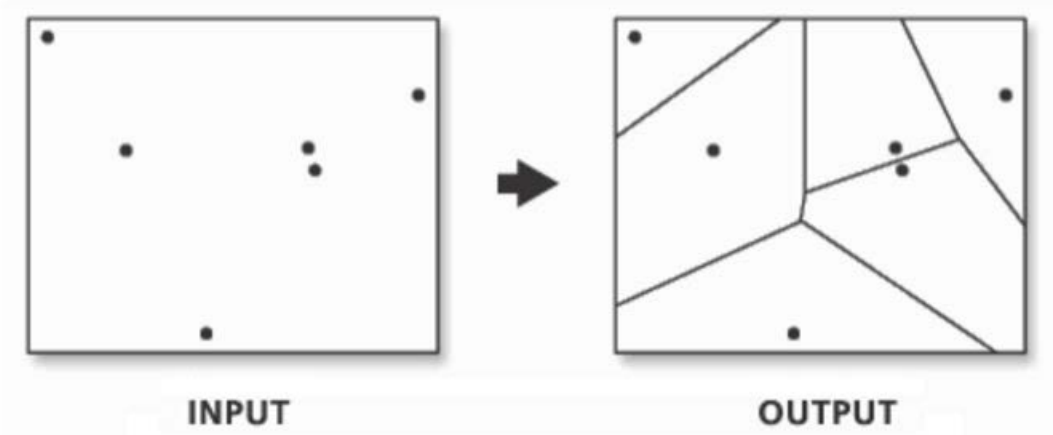
1. Thiessen Polygons

Thiessen polygons, also known as Voronoi diagrams, are named after the American Meteorologist Alfred H. Thiessen. Thiessen polygons are essentially Voronoi diagram (named after Ukrainian Mathematician Georgy Voronoi) that are used in geophysics and meteorology to analyze spatially distributed data (Brassel & Reif, 2010).

Broadly speaking, according to Brassel and Reif (2010), Thiessen polygons are calculated starting with a finite set of sample points in a two dimensional plane. The polygons, one per sample point, partition the plane into convex polygons so that any location in a polygon is closer to its sample point than to any other sample point. Furthermore, the line segments forming the polygon boundaries are equidistant to the nearest sample points. An example of Thiessen polygons is illustrated in Figure 6.

Polygons are essentially formed by a set of points. Keeping this in mind, a median line between two polygons can be calculated by extracting points of polygons and applying Thiessen polygons for each of them within an appropriate bounding box. In this study, we use Thiessen polygons to find the median line between intersected areas that represent territorial waters of islands.

Figure 6. Illustration of Thiessen polygons. Source: ArcGIS (2015).



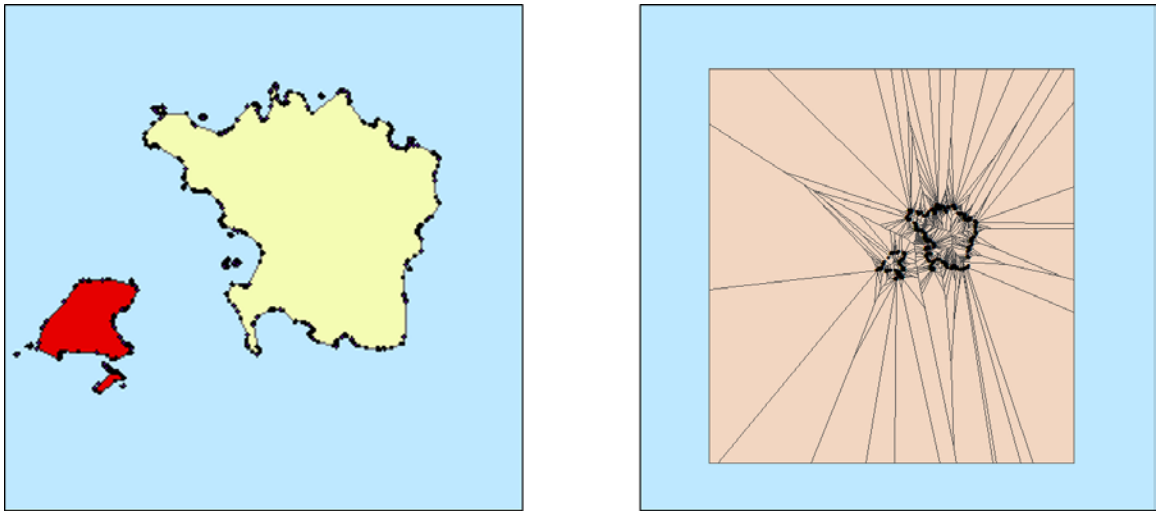
2. Spatial Operations

After importing the shape files containing polygon coordinates created via ArcMAP 10.3 tool into the R statistical environment, we categorize polygons of territories into three groups in terms of sovereignty. These three categories are Gray Zone, Greek, and Turkish. We use the following approach to calculate the territorial water of each island.

1. If the expansion areas of a disputed island and any other territory intersect, create a list of coordinates of every point that forms these polygons of islands as shown in the left box of in Figure 7.

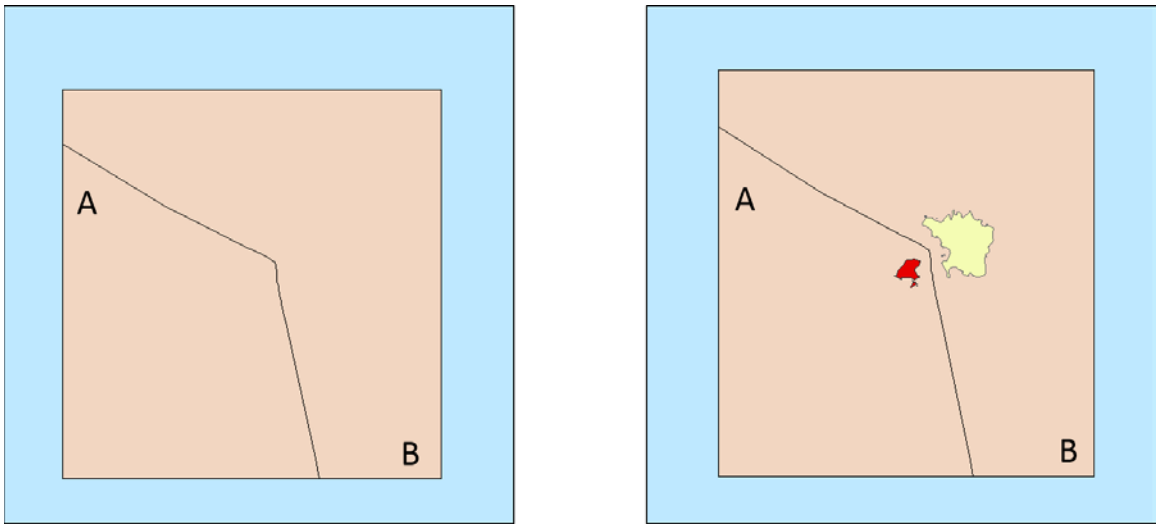
2. Using these points, create Thiessen polygons setting an appropriate bounding box as in right hand side of Figure 7. For the six-mile scenario, the bounding box is the extension of the 12-mile buffered area of the disputed island. On the other hand, the extension of the 24-mile buffered area is used for the 12-mile scenario.

Figure 7. Illustration of Step 1 and Step 2.



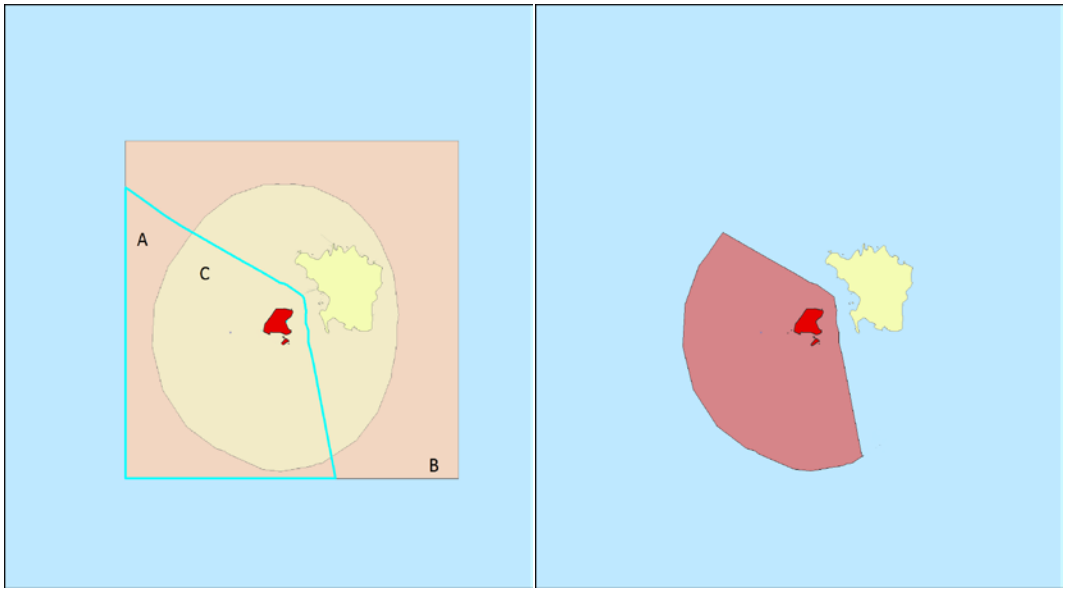
3. Find the median line between the islands and merge all the Thiessen polygons remaining on each side of the median line. Thereby, form a 2-polygon feature (area A and area B) divided by the median line, as seen in Figure 8.

Figure 8. Illustration of Step 3.



4. Extract the area where the six-mile extension (in second scenario, the 12-mile extension) and the related merged Thiessen polygon intersect. As seen in Figure 9, we extract the intersection between A and C.

Figure 9. Illustration of Step 4.



5. If a disputed island intersects with more than one territory, first repeat steps 1–4 for each pair of selected islands and territory, and then calculate the intersection area of all extracted areas.

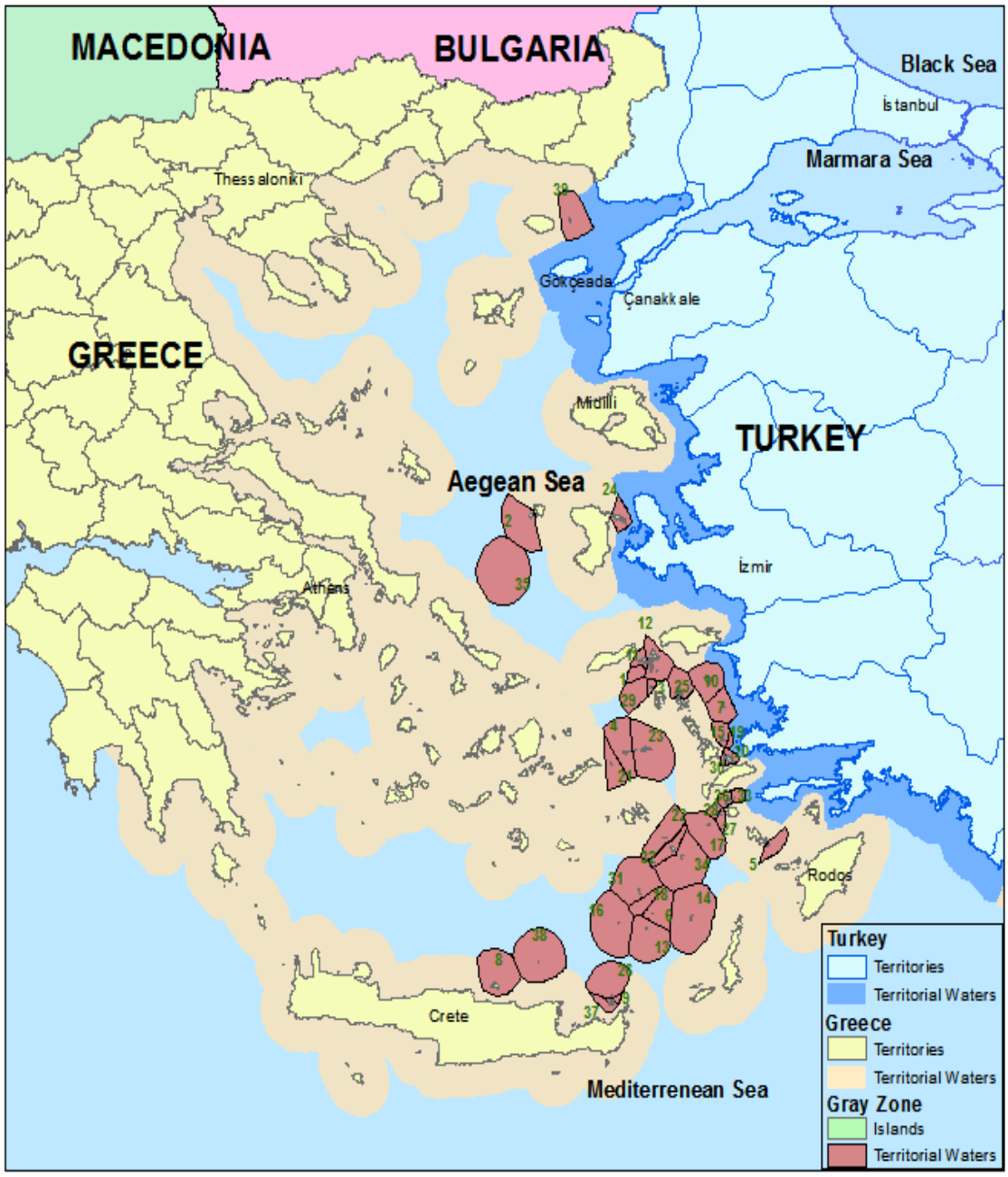
6. If a disputed island does not intersect with any undisputed territory, expand the islands territorial water to six miles (in the second scenario, 12 miles).

After these operations, we obtain our individual territoral water areas for each disputed island. As the Turkish thesis and current status quo proclaim, the Aegean map, including the expansion of territorial waters by six nautical miles, is presented in Figure 10. Figure 11 illustrates the expansion of territorial waters by 12 nautical miles according to the Greek thesis. That concludes our spatial analysis and the preparation of our dataset for the application of game theory in an arbitration scheme.

Figure 10. Six-nautical-mile expansion of territorial waters in the Aegean Sea.

Base maps sourced and adapted from “Tur_adm” and “Prefectures HEMCO.”

Figure 11. Twelve-nautical-mile expansion of territorial waters in the Aegean Sea.



Base maps sourced and adapted from “Tur_adm” and “Prefectures HEMCO.”

THIS PAGE INTENTIONALLY LEFT BLANK

IV. AN ARBITRATION SOLUTION

In this chapter, we use the Nash arbitration scheme to propose a solution for how to divide the disputed islands between Greece and Turkey. The approach involves three steps:

1. For each country, convert each island's six parameters in Chapter III, Section B into utilities between 0 and 1.
2. For each country, use AHP to calculate the weight of each parameter, and compute each island's composite utility value.
3. Apply the Nash arbitration scheme to propose a bargaining solution for dividing the disputed islands between Greece and Turkey.

A. CONVERTING VALUES TO UTILITIES

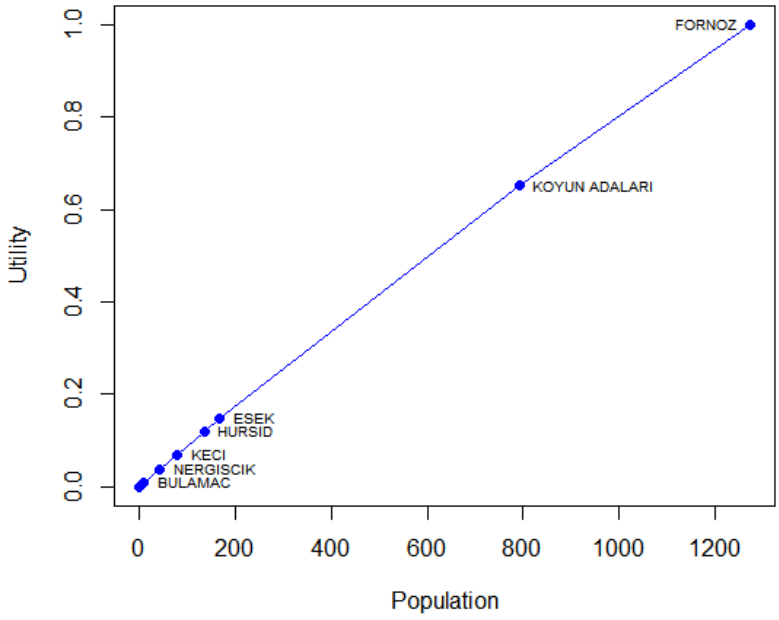
We have a list of 39 disputed islands. Each island is defined by six parameters, namely its perimeter, area, population, distance to Greece, distance to Turkey, and territorial water area. Since the units of these parameters are not the same, we need to convert each parameter to a utility between 0 and 1, before we can create a single utility value for each disputed island.

Three different utility functions are considered in compliance with analytical judgment and the nature of the measure: a linear function, an increasing exponential function, and a decreasing exponential function.

First, consider the population parameter. There are seven islands that are populated, and five of them have fewer than 200 people. The only two islands that have more than 200 people are Koyun with 792 people and Fornoz with 1274 people. Unpopulated islands take a 0 utility value as the minimum value, and Fornoz takes 1 as the maximum value. Since most islands have no population or a very small population, a linear utility curve appears to be appropriate. Equation (1) is used to calculate an island's utility value for population, where a represents the minimum population value of the set and b represents the maximum population value. A linear utility curve is illustrated as shown in Figure 12.

$$f(x) = \frac{x - a}{b - a} \tag{1}$$

Figure 12. Population utility curve.

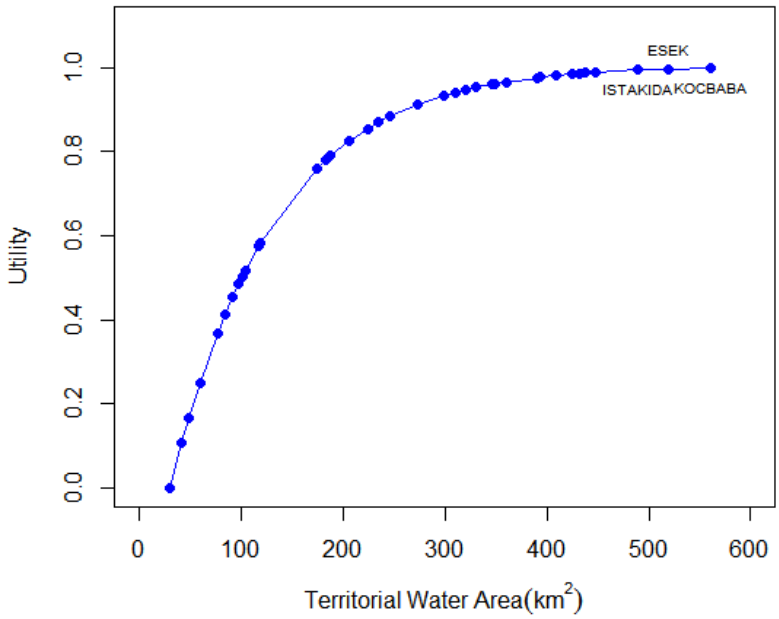


The perimeter, area, and territorial water area utilities are calculated by increasing exponential utility curves. In the calculation of these utilities, exponential scaling is used where a stands for minimum value and b stands for maximum value, in the value set. The parameter R is used as a smoothing parameter, which can be chosen by the user. Equation (2) is used for the scaling:

$$f(x) = \frac{1 - e^{-(\frac{x-a}{R})}}{1 - e^{-(\frac{b-a}{R})}} \tag{2}$$

The smoothing parameter R is selected as the value that ensures utilities are spread evenly in [0, 1]. To do so, we choose R so that the sample variance of the utility values is 1/12, which is the variance of the uniform (0, 1) random variable. An example of an increasing exponential utility curve is illustrated in Figure 13.

Figure 13. Territorial water area (six-nautical-mile) utility curve.

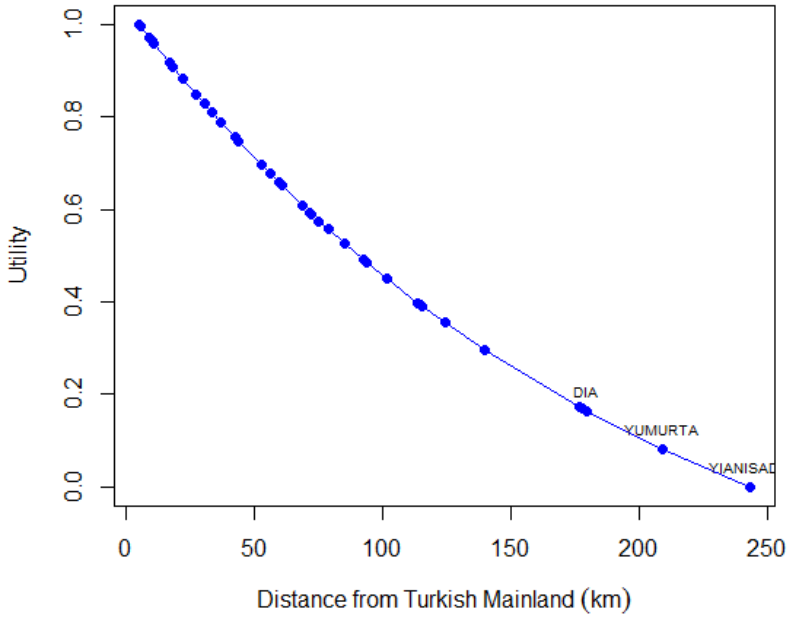


On the other hand, the distance to Turkey and Greece utilities are calculated via decreasing functions, due to the fact that each country prefers an island closer to its mainland. In Equation (3), a stands for minimum distance and b stands for maximum distance.

$$f(x)=\frac{e^{(\frac{b-x}{R})}-1}{e^{(\frac{b-a}{R})}-1} \tag{3}$$

We choose the smoothing parameter R as in Equation (2). An example of converting values into utility values via decreasing exponential utility curves is illustrated in Figure 14.

Figure 14. Distance from Turkey utility curve.



B. APPLYING THE ANALYTICAL HIERARCHY PROCESS TO COMPUTE COMPOSITE UTILITIES

In this section, we apply AHP to calculate weights of the parameters and compute country-based composite utilities of each disputed island for each case. Section 1 reviews the AHP and the calculation of the weights for each parameter. Section 2 presents the composite utilities of the disputed islands for each country in both six-mile and 12-mile territorial water scenarios.

1. Weighting Parameters

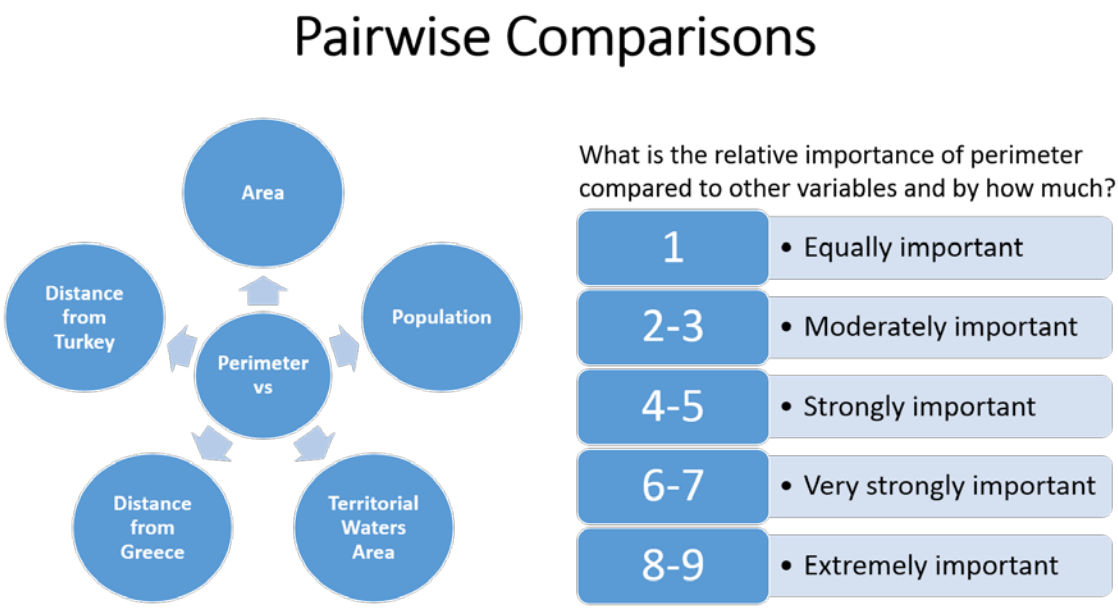
To weight the parameters, we use AHP. Generally speaking, AHP is a methodology that uses pairwise comparison between two parameters to construct a composite utility for all parameters. In pairwise comparisons, we use relative measurements to compare the importance between two parameters (Brunelli, 2016). "The ultimate scope of the AHP is that of using pairwise comparisons between alternatives as inputs, to produce a rating of alternatives, compatibly with the theory of relative measurement" (Brunelli, 2016).

Since AHP is used as a decision-making model, it helps the user control criteria and hierarchies among the parameters. As stated in Saaty (2016), “it is designed to cope with both the rational and the intuitive to select the best from a number of alternatives evaluated with respect to several criteria. In this process, the decision maker carries out simple pairwise comparison judgments which are then used to develop overall priorities for ranking the alternatives.” In other words, by determining relative importance between parameters, the user specifies which parameter is more important than the other one and by how much. Therefore, AHP allows the user to prioritize the parameters.

In this thesis, AHP is used to make pairwise comparisons between model parameters, so that we can score our utilities in a weighted way. For the application of game theory in the next step, the two players, Turkey and Greece, should have their own utility values for each island. Therefore, AHP appears to be a reasonable way to calculate the utility of each disputed island for each country.

The weighting process is done after the prioritization process of each country is completed. Each parameter of the model is compared to the other parameters in a scale from 1 to 9, as seen in Figure 15. For instance, if the area parameter is strongly more important than the perimeter parameter for Turkey, the relative importance of the area to perimeter is 5, and the relative importance of perimeter to area is 1/5. Applying the pairwise comparison to all pairs, we construct a 6 x 6 matrix.

Figure 15. Weighting parameters by pairwise comparisons.



As an example, Table 2 shows hypothetical results for Turkey, and those for Greece are shown in Table 3. The prioritization process is done using the author's subjective observation and intuitive insights and according to the main interest of the countries. For example, since most of the population of the selected islands is Greek the population parameter is more important than the other parameters in the priorities of Greece. Specifically, in Turkey's priority matrix, the population parameter has a relative importance of 1/7 versus the area parameter, while in the Greek priority matrix it is 1/3. Overall, the population parameter is more important to Greece.

Likewise, an island's distance to the Turkish mainland is more important to Turkey, while the island's distance to Greece is more important for Greece. All prioritizations are subject to the opinions of the author and are chosen to reflect the interests of the countries in the region. The results may be different if the process is conducted by the experts of this topic.

Table 2. Pairwise comparisons for Turkey.

	Perimeter	Area	Population	Distance to Greece	Distance to Turkey	Territorial Water Area
Perimeter	1	1/7	1/3	1/5	1/9	1/9
Area	7	1	3	7	1/3	1/3
Population	3	1/3	1	3	1/3	1/5
Distance to Greece	5	1/7	1/3	1	1/7	1/7
Distance to Turkey	9	3	3	7	1	3
Territorial Water Area	9	3	5	7	1/3	1

Table 3. Pairwise comparisons for Greece.

	Perimeter	Area	Population	Distance to Greece	Distance to Turkey	Territorial Water Area
Perimeter	1	1/7	1/7	1/9	1/5	1/9
Area	7	1	3	1/7	5	1/7
Population	7	1/3	1	5	7	3
Distance to Greece	9	7	1/5	1	7	3
Distance to Turkey	5	1/5	1/7	1/7	1	1/7
Territorial Water Area	9	7	1/3	1/3	7	1

After the prioritization process for each country, we compute the principal right eigenvector to produce the weight of each parameter. The weights of the parameters for each country are shown in Table 4.

Table 4. Weights of parameters.

Country	**Perimeter**	**Area**	**Population**	**Tw_Area**	**Distance_Gr**	**Distance_Tr**
Turkey	0.0244	0.1759	0.0845	0.2881	0.0454	0.3816
Greece	0.0222	0.1312	0.2890	0.2210	0.2927	0.0436

2. Calculating Composite Utilities

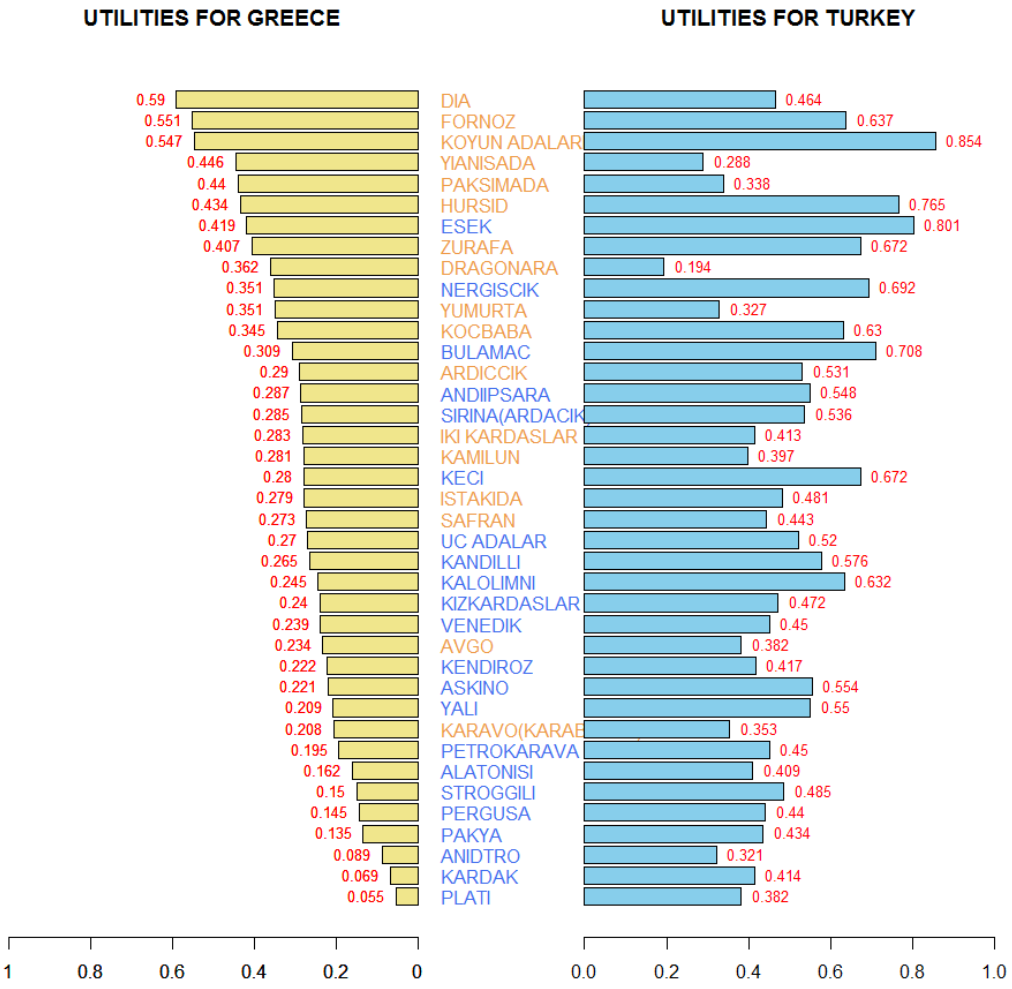
After the calculation of weights, we are ready to compute country-based composite utilities for each disputed island. For each country, the utility for a disputed island is the weighted average over the island's six parameter utilities, with the weights given in Table 4.

In the six-mile territorial waters scenario (Turkish thesis), the composite utilities of the disputed islands are illustrated in Figure 16. For this scenario, the five most important islands for Turkey are in sequence: Koyun, Eşek, Hurşid, Bulamaç, and Nergisçik. For Greece they are: Dia, Fornoz, Koyun, Paksimada, and Hurşid.

In the 12-mile territorial waters scenario (Greek thesis), the islands of Koyun, Eşek, Hurşid, Koçbaba, and Keçi are the five most important islands to Turkey. On the other hand, for Greece, they are Dia, Fornoz, Koyun, Yianisada, and Paksimada as shown in Figure 17.

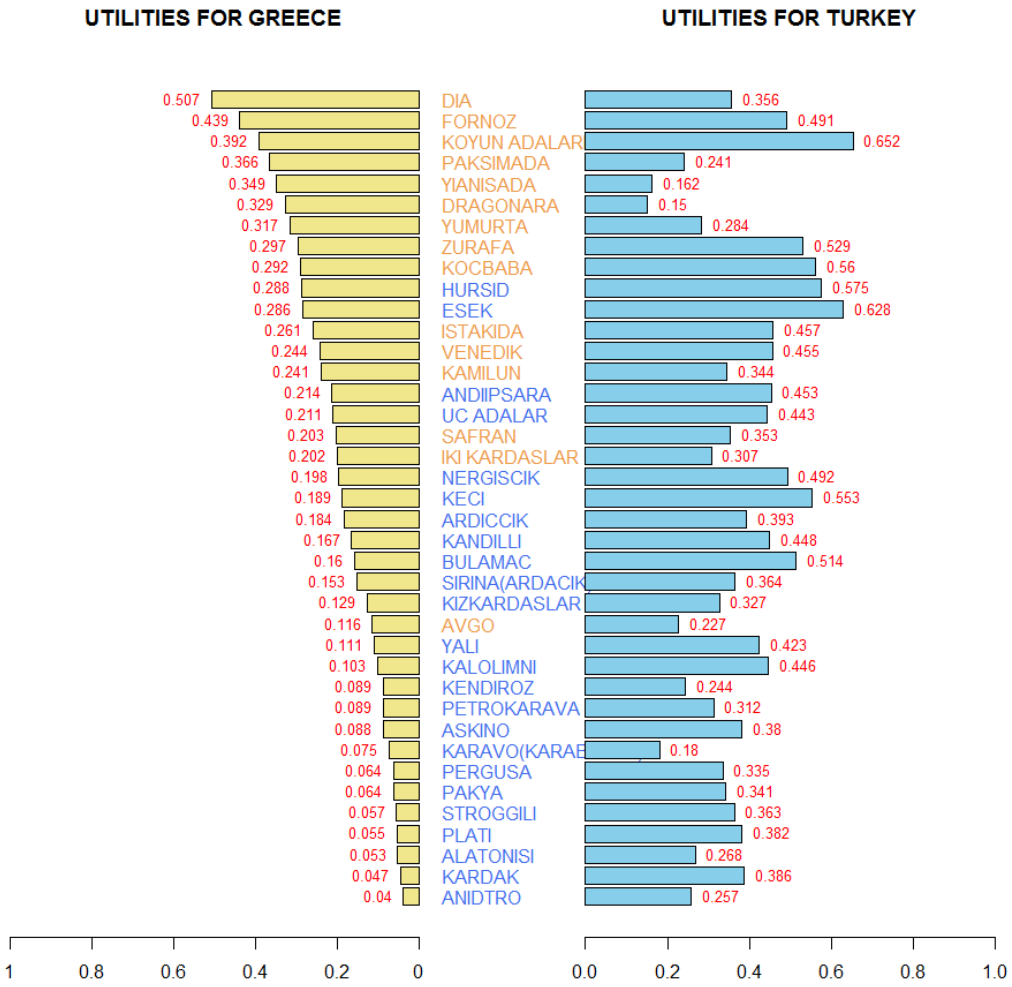
The ordering of the utilities shows that the islands that have a larger area of territorial waters and are closer to the Turkish mainland are more important to Turkey. On the other hand, islands that are populated and closer to the Greek mainland are more important to Greece.

Figure 16. Weighted utilities of the islands for the six-nautical-mile expansion of territorial waters.



*Yellow islands go to Greece and blue islands go to Turkey after the application of Nash arbitration scheme

Figure 17. Weighted utilities of the islands for the twelve-nautical-mile expansion of territorial waters.



*Yellow islands go to Greece and blue islands go to Turkey after the application of Nash arbitration scheme

C. NASH ARBITRATION SCHEME

This section uses the Nash arbitration scheme to divide the disputed islands between Turkey and Greece. Section 1 reviews the methodology. Section 2 presents the results.

1. Methodology

The Nash arbitration scheme provides a solution for a two-player cooperative game. In this game, two players have a set of solutions, which includes an initial point that stands for a status-quo outcome if the two players cannot reach an agreement. "The outcome in any particular case will depend on the personalities and bargaining abilities of the two players" (Owen, 2013). Therefore, a plausible arbitration scheme should satisfy six axioms (Straffin, 1993; Owen, 2013):

1. Individual rationality: In the arbitration solution, both players should do no worse than the status-quo outcome.

2. Feasibility: The arbitration solution should lie in a convex polygon in the coordinate system that represents the bargaining set.

3. Pareto optimality: In simple terms, Pareto optimality refers to a solution set in which it is impossible to make any player's gain better off without making other player's worse ("Pareto efficiency, " n.d.). The arbitration solution should be Pareto optimal.

4. Independence of irrelevant alternatives: Suppose we identify an arbitration solution for an arbitration problem. When the feasible set is expanded, the new solution point can either be the same point or one of the new points that are added to the old set; the new solution point cannot be another point in the old set.

5. Independence of linear transformations: If the utility of either player is transformed by a linear function, then the solution point is also transformed by the same function.

6. Symmetry: If the convex polygon representing the bargaining set is symmetric about the line of slope +1 passing through both origin and the status-quo point, then the arbitration solution should reward the same value to each player.

John Nash (1950) showed that there is a unique solution that meets all six axioms simultaneously, and the solution is referred to as the Nash arbitration solution. We apply the Nash arbitration scheme to our problem. This creates a reconciliation point between the countries by a partition of the islands according to each player's utilities. Let us define a game where u represents the total utility of the islands for Turkey and v represents overall utility for Greece. In that sense, we can interpret them as

$$u = \sum_{i=1}^{n=39} x_i t_i \,, \tag{4}$$

where, t_i is the utility of island i for Turkey, and $x_i = 1$ if island i is taken by Turkey, and $x_i = 0$ otherwise. Similarly,

$$v = \sum_{i=1}^{n=39} y_i g_i \,, \tag{5}$$

where, g_i is the utility of island i for Greece, and $y_i = 1$ if island i is taken by Greece, and $y_i = 0$ otherwise.

In our model, we take the status-quo point (represented as u^* and v^*) as 0 for both countries, which reflects the situation where both countries get nothing, in case either country refuses the arbitration solution.

Nash showed that the unique solution that meets the six axioms presented in this section is the point that maximizes the function

$$g(u,v) = (u - u^*)(v - v^*) \,, \tag{6}$$

where,

$$\begin{aligned} & u \geq u^* \\ & v \geq v^* \\ & x_i + y_i = 1, \text{ for } \forall i \in \{1, 2, ..., 39\} \end{aligned} \tag{7}$$

2. Results

We run this model twice, once for the case where the territorial waters are six nautical miles, and once for the case where the territorial waters are 12 nautical miles. In the case of six nautical miles, the solution awards 22 of the disputed islands to Turkey and the other 17 islands to Greece. In the case of 12 nautical miles, the solution awards 24 islands to Turkey and the other 15 islands to Greece. The sovereignty of the islands is listed in Table 5 and illustrated in Figures 16 and 17, respectively, where blue stands for Turkey and yellow stands for Greece. The map in Figure 18 shows the results for the six-mile scenario, and the map in Figure 19 shows the results for the 12-mile scenario.

Table 5. Solution of the arbitration scheme based on case and country.

ID	Name of the Island	6 nm Case	12 nm Case		ID	Name of the Island	6 nm Case	12 nm Case
1	ALATONISI	TURKEY	TURKEY		21	KENDIROZ	TURKEY	TURKEY
2	ANDIIPSARA	TURKEY	TURKEY		22	KIZKARDASLAR	TURKEY	TURKEY
3	ANIDTRO	TURKEY	TURKEY		23	KOCBABA	GREECE	GREECE
4	ARDICCIK	GREECE	TURKEY		24	KOYUN	GREECE	GREECE
5	ASKINO	TURKEY	TURKEY		25	NERGISCIK	TURKEY	TURKEY
6	AVGO	GREECE	GREECE		26	PAKSIMADA	GREECE	GREECE
7	BULAMAC	TURKEY	TURKEY		27	PAKYA	TURKEY	TURKEY
8	DIA	GREECE	GREECE		28	PERGUSA	TURKEY	TURKEY
9	DRAGONARA	GREECE	GREECE		29	PETROKARAVA	TURKEY	TURKEY
10	ESEK	TURKEY	TURKEY		30	PLATI	TURKEY	TURKEY
11	FORNOZ	GREECE	GREECE		31	SAFRAN	GREECE	GREECE
12	HURSID	GREECE	TURKEY		32	SIRINA	TURKEY	TURKEY
13	IKI KARDASLAR	GREECE	GREECE		33	STROGGILI	TURKEY	TURKEY
14	ISTAKIDA	GREECE	GREECE		34	UC ADALAR	TURKEY	TURKEY
15	KALOLIMNI	TURKEY	TURKEY		35	VENEDIK	TURKEY	GREECE
16	KAMILUN	GREECE	GREECE		36	YALI	TURKEY	TURKEY
17	KANDILLI	TURKEY	TURKEY		37	YIANISADA	GREECE	GREECE
18	KARAVO	GREECE	TURKEY		38	YUMURTA	GREECE	GREECE
19	KARDAK	TURKEY	TURKEY		39	ZURAFA	GREECE	GREECE
20	KECI	TURKEY	TURKEY		-	-	-	-

Figure 18. Aegean map after partition for six-nautical-mile extension of territorial waters.

Base maps sourced and adapted from “Tur_adm” and “Prefectures HEMCO.”

Figure 19. Aegean map after partition for twelve-nautical-mile extension of territorial waters.

*Base maps sourced and adapted from “Tur_adm” and “Prefectures HEMCO.”

In both cases, it is significant that the islands that are closer to the Turkish mainland and have a larger area of territorial waters tend to be ceded to Turkey, since they are relatively more important to Turkey. At the same time, Greece receives the islands that have larger population and are closer to Greek mainland, as they are relatively more important to Greece.

As seen in Table 5, in the case of six nautical miles of territorial waters, three islands, Ardıççık, Hurşid, and Karavo, go to Greece; while in the case of 12 nautical miles of territorial waters, they go to Turkey. On the other hand, the Island of Venedik goes to Turkey in the case of six nautical miles of territorial waters, while in the case of 12 nautical miles of territorial waters, it goes to Greece.

In the case of six nautical miles of territorial waters, the five most important islands for Turkey are in sequence Koyun, Eşek, Hurşid, Bulamaç, and Nergisçik; while for Greece, they are Dia, Fornoz, Koyun, Paksimada, and Hurşid. At the end of the partition, Turkey gets Eşek, Bulamaç, and Nergisçik of these; however, Greece takes all five of the most significant islands. In the case of 12 nautical miles of terrtitorial waters, the islands of Koyun, Eşek, Hurşid, Koçbaba, and Keçi are the five most important islands to Turkey; while, for Greece, they are Dia, Fornoz, Koyun, Yianisada, and Paksimada. At the end of the arbitration Turkey gets Eşek, Hurşid, and Keçi of these; however, Greece takes all five of the most significant islands.

It is worth pointing out that increasing the territorial waters from six nautical miles to 12 nautical miles does not necessarily increase the territorial waters of every island, since some islands sit close together. Consequently, changing the territorial water distance has a minor impact on the arbitration solution.

V. CONCLUSION

This thesis demonstrates an approach to reconcile disputed islands between Turkey and Greece, by applying spatial analysis, utility theory, AHP, and the Nash arbitration scheme. We selected 39 disputed islands in the Aegean Sea according to location, size, and disputability, and considered six parameters: perimeter, area, population, distance to Greece, distance to Turkey, and territorial water area. We used spatial analysis tools to process the data, applied utility theory and AHP to compute how important each island is to each country, and then used the Nash arbitration scheme to divide the islands equitably between the two countries.

Our approach relies upon several subjective assessments. First, in selection of the islands, we only focused on islands in the Aegean Sea. Therefore, some disputed islands south of Girit (Crete) are not included in the study, since these islands are considered to be in the Mediterranean Sea. Second, since the Island of Girit (Crete) is significantly larger than any other island in the region, it is considered part of the Greek mainland when calculating the distance between a disputed island and the Greek mainland. Third, when using AHP, priorities were assessed subjectively by the author based on limited knowledge about the interests of the countries. Finally, when applying the Nash arbitration scheme, we assigned the status-quo point to have 0 utility value for both countries.

There are several different ways to extend this work. First, we can add other parameters, such as the natural resources on each island and merchant ship intensity within territorial waters of each island. Second, when applying AHP, government officials or scholars at research institutions may be able to provide a more objective assessment. Finally, our proposed approach can also be applied to other conflicted (or non-conflicted) regions, such as the South China Sea.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX. LIST OF AEGEAN ISLANDS

ID	Turkish Name	Greek Name	Sovereignty
1	AGIO OROS	AGIO OROS	GREEK
2	AHIKERYA	IKARIA	GREEK
3	ALATONISI	ALATONISI	GRAY ZONE
4	ALIMYA	ALIMIA	GREEK
5	ANAFIYE	ANAFI	GREEK
6	ANANES	ANANES	GREEK
7	ANDIIPSARA	ANTIIPSARA	GRAY ZONE
8	ANDRE	ANDROS	GREEK
9	ANIDRO	ANIDHROS	GREEK
10	ANIDTRO	ANIDTRO	GRAY ZONE
11	ANTALYA	ANTALYA	TURKISH
12	ARDICCIK	KINAROS	GRAY ZONE
13	ARSURA	PSATHURA	GREEK
14	ASKINO	ANDITILOS	GRAY ZONE
15	AVGO	AVGO	GRAY ZONE
16	AYDIN	AYDIN	TURKISH
17	BALIKESIR	BALIKESIR	TURKISH
18	BATNOZ	PATMOS	GREEK
19	BIBER	PIPERI	GREEK
20	BOLUKENDIRE/POLIKANDROS	FOLEGANDROS	GREEK
21	BOZBABA	AGIOS EVSTRATIOS	GREEK

22	BOZCAADA	BOZCAADA	TURKISH
23	BULAMAC	FARMAKONISI	GRAY ZONE
24	CANAKKALE	CANAKKALE	TURKISH
25	CAROS	GYAROS	GREEK
26	CUHA	KYTHIRA	GREEK
27	DEGIRMENLIK	MILOS	GREEK
28	DELOS	DILOS	GREEK
29	DIA	DIA	GRAY ZONE
30	DRAGONARA	DRAGONARA	GRAY ZONE
31	EDIRNE	EDIRNE	TURKISH
32	EGRIBOZ	EVVOIA	GREEK
33	ESEK	AGATHONISI	GRAY ZONE
34	ESKINO	SHOINOUSSA	GREEK
35	ESKINOS	SIKINOS	GREEK
36	FLAKONDRA	FLAKONERA	GREEK
37	FORNOZ	FURNI	GRAY ZONE
38	GIRIT	CRETE	GREEK
39	GOKCEADA	IMROZ	TURKISH
40	GUMUS	KIMILOS	GREEK
41	HERKE	HALKI	GREEK
42	HIRSIZ	PIPERI	GREEK
43	HRISTIYAN	HRISTIANI	GREEK
44	HURSID	FYMENA	GRAY ZONE

45	IKI KARDASLAR	UNIANISIA	GRAY ZONE
46	ILEKI	TILOS	GREEK
47	INCIRLI	NISYROS	GREEK
48	IPSARA	PSARA	GREEK
49	ISKABOLOS	SKOPELOS	GREEK
50	ISKADOS	SKIATHOS	GREEK
51	ISKANDIL	SKONTZURA	GREEK
52	ISKIRI	SKYROS	GREEK
53	ISTAKIDA	ASTAKIDONISIA	GRAY ZONE
54	ISTANBULYA	ASTYPALEA	GREEK
55	ISTANKOY	KOS	GREEK
56	ISTANOS	DONOUSSA	GREEK
57	ISTAPORYA	STAPODIO	GREEK
58	ISTENDIL	TINOS	GREEK
59	IZMIR	IZMIR	TURKISH
60	KALOLIMNI	KALOLIMNOS	GRAY ZONE
61	KAMILUN	CHAMILI	GRAY ZONE
62	KANDILLI	KANDELIOUSSA	GRAY ZONE
63	KARAVI	KARAVI	GREEK
64	KARAVO(KARABONEZ)	KARAVONISI	GRAY ZONE
65	KARDAK	IMIA	GRAY ZONE
66	KARO	KEROS	GREEK
67	KASOT	KASOS	GREEK

68	KECI	PSERIMOS	GRAY ZONE
69	KELEMEZ	KALYMNOS	GREEK
70	KENDIROZ	LIADI	GRAY ZONE
71	KERPE	KARPATHOS	GREEK
72	KIRLANGIC	ALONISSOS	GREEK
73	KIZKARDASLAR	ADELFOI	GRAY ZONE
74	KOCBABA	LEVITHA	GRAY ZONE
75	KOYUN ADALARI	OUINOUSSES	GRAY ZONE
76	KOYUNLUCA	SERIFOS	GREEK
77	KUCUK ANAFI	PAKYA/MAKRA	GREEK
78	KUCUK CUHA	ANTIKYHIRA	GREEK
79	KUCUK DEGIRMENLIK	ANDIMILOS	GREEK
80	KUCUK PARA	ANTIPAROS	GREEK
81	LERYOZ	LEROS	GREEK
82	LIMNI	LIMNOS	GREEK
83	LIPSO	LIPSOS	GREEK
84	MANISA	MANISA	TURKISH
85	MEIS	KASTELLORIZO	GREEK
86	MIDILLI	LESVOS	GREEK
87	MISKIN	NIMOS	GREEK
88	MOKENE	MYKONOS	GREEK
89	MUGLA	MUGLA	TURKISH
90	MURTED	KEA	GREEK

91	N. ANATOLIKIS ATTIKIS	N. ANATOLIKIS ATTIKIS	GREEK
92	N. ARGOLIDAS	N. ARGOLIDAS	GREEK
93	N. ARKADIAS	N. ARKADIAS	GREEK
94	N. ATHINION	N. ATHINION	GREEK
95	N. CHALKIDIKIS	N. CHALKIDIKIS	GREEK
96	N. DRAMAS	N. DRAMAS	GREEK
97	N. DYTIKIS ATTIKIS	N. DYTIKIS ATTIKIS	GREEK
98	N. EVROU	N. EVROU	GREEK
99	N. FTHIOTIDAS	N. FTHIOTIDAS	GREEK
100	N. IMATHIAS	N. IMATHIAS	GREEK
101	N. KAVALAS	N. KAVALAS	GREEK
102	N. KORINTHOU	N. KORINTHOU	GREEK
103	N. LAKONIAS	N. LAKONIAS	GREEK
104	N. LARISAS	N. LARISAS	GREEK
105	N. MAGNISIAS	N. MAGNISIAS	GREEK
106	N. PELLAS	N. PELLAS	GREEK
107	N. PIERIAS	N. PIERIAS	GREEK
108	N. PIREOS KE NISON	N. PIREOS KE NISON	GREEK
109	N. RODOPIS	N. RODOPIS	GREEK
110	N. SERRON	N. SERRON	GREEK
111	N. THESSALONIKIS	N. THESSALONIKIS	GREEK
112	N. VIOTIAS	N. VIOTIAS	GREEK
113	N. XANTHIS	N. XANTHIS	GREEK

114	NAKSA	NAXOS	GREEK
115	NERGISCIK	ARKI	GRAY ZONE
116	PAKSIMADA	PAXIMADA	GRAY ZONE
117	PAKYA	PACHEIA	GRAY ZONE
118	PARA	PAROS	GREEK
119	PELAGOS	PELAGROS	GREEK
120	PERGUSA	PERGUSA	GRAY ZONE
121	PETROKARAVA	PETROKARAVA	GRAY ZONE
122	PLATI	PLATI	GRAY ZONE
123	POLINO	POLIEGOS	GREEK
124	RAKLIYA/ORENLI	IRAKLIA	GREEK
125	RAPILA	VELOPULO	GREEK
126	RODOS	RODOS	GREEK
127	SAFRAN	SOFRANO	GRAY ZONE
128	SAKIZ	KHIOS	GREEK
129	SANTORON	SANTORINI	GREEK
130	SEMADIREK	SAMOTHRAKI	GREEK
131	SERFO	SERIFOPULA	GREEK
132	SEYTAN	GIOURA	GREEK
133	SIGIRCIKLAR	RINEIA	GREEK
134	SIRA	SYROS	GREEK
135	SIRINA(ARDACIK)	SYRNA	GRAY ZONE
136	SISAM	SAMOS	GREEK

137	SOMBEKI	SYMI	GREEK
138	STROGGILI	STROGGILI	GRAY ZONE
139	TASOZ	TASOS	GREEK
140	TEKIRDAG	TEKIRDAG	TURKISH
141	TERME	KYTHNOS	GREEK
142	UC ADALAR	PLAKIDHA	GRAY ZONE
143	UNYE	IOS	GREEK
144	UZUNCA	MAKRONISOS	GREEK
145	VENEDIK	KALOGEROS	GRAY ZONE
146	YABAN	OFIDOUSSA	GREEK
147	YALI	YIALI	GRAY ZONE
148	YAMURGI	AMORGOS	GREEK
149	YAVUZCA/ISPINOS	SIFNOS	GREEK
150	YIANISADA	GIANISADA	GRAY ZONE
151	YILAN	DHRAGONISI	GREEK
152	YUMURTA	AVGO LASITHOU	GRAY ZONE

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

Aegean dispute. (n.d.). In *Wikipedia*. Retrieved May 3, 2016, from https://en.wikipedia.org/wiki/Aegean_dispute#.22Grey_zones.22

Ak, G. (2014a). Tarih, deniz ve egemenlik: Ege'nin Isporadları "Menteşe Adaları"nın dünü ve bugünü [History, sea and sovereignty: Past and current times of the Aegean Sporades "Menteşe Islands"]. *Journal of Modern Turkish History Studies, XIV*(29), 283–313.

Ak, G. (2014b). Ghost in the Aegean: Turkish-Greek maritime boundary, situation and impacts. *Cumhuriyet Tarihi Araştırmaları Dergisi*, *20*, 255–288.

ArcGIS. (2015). Mapping Platform (Version 10.3.1) [Computer Software]. Retrieved December 6, 2015 from https://www.nps.edu/Technology/SoftwareLib/Auth/index.htm

Brassel, K.E., & Reif,D. (2010, September 3). A procedure to generate Thiessen polygons. *Geographical Analysis, 11*(3), 289–303. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1538-4632.1979.tb00695.x/pdf

Brinkhoff, T. (2015, December 27). Greece. Retrieved from http://www.citypopulation.de.

Brunelli, M. (2016). *Introduction to the analytic hierarchy process*. New York, NY: Springer, 2014.

Heraclides, A. (2010). *The Greek-Turkish conflict in the Aegean: Imagined Enemies*. London, England: Palgrave Macmillan.

Kurumahmut, A., & Başeren, S. H. (2004). *The twilight zones in the Aegean: (Un)forgotten Turkish islands*. Ankara, Turkey: Turkish Historical Society Printing House.

Mann, S. (2001). T*he Greek-Turkish dispute in the Aegean Sea: Its ramifications for NATO and the prospects for resolution* (Master's thesis). Retrieved from Calhoun: http://calhoun.nps.edu/bitstream/handle/10945/2684/01Mar_Mann.pdf?sequence=3

Nash, J. (1950). The bargaining problem. *Econometrica,* 18, 155–162.

Owen, G. (2013). *Game theory, 4th edition*. London, England: Emerald Group Publishing Limited.

Pareto efficiency. (n.d.). In *Wikipedia*. Retrieved May 10, 2016, from https://en.wikipedia.org/wiki/Pareto_efficiency

Prefectures HEMCO. (2014). Retrieved November 15, 2015, from http://opendatagortynia.gr/en/group/geography

R Core Team. (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved May 19, 2015, from http://www.R-project.org/.

Saaty, T. L. (2016). *Models, methods, concepts & applications of the analytic hierarchy process*. New York: Springer.

Straffin, P. D. (1993). *Game theory and strategy*. Washington, DC: Mathematical Association of America.

Treaty of peace with Turkey. (1923). In *the Treaties of Peace 1919–1923, vol. II*. New York, NY: Carnegie Endowment for International Peace. Retrieved May 11, 2016, from http://sam.baskent.edu.tr/belge/Lausanne_ENG.pdf

Tur_adm. (n.d.). Retrieved November 11, 2015, from http://www.gadm.org/download

UNHCR. (2015, July 9). Total number of Syrian refugees exceeds four million for first time. Retrieved from http://www.unhcr.org/559d67d46.html

United Nations. (1982a). United Nationals Convention of the Law of the Sea Part II: Territorial Sea and Contiguous Zone. Retrieved May 11, 2016, from http://www.un.org/depts/los/convention_agreements/texts/unclos/part2.htm

United Nations. (1982b). United Nationals Convention of the Law of the Sea Part IX. Enclosed or Semi-Enclosed Seas. Retrieved May 11, 2016, from http://www.un.org/depts/los/convention_agreements/texts/unclos/part9.htm

United Nations. (1982c). United Nationals Convention of the Law of the Sea Part XVI. General Provisions. Retrieved May 11, 2016, from http://www.un.org/depts/los/convention_agreements/texts/unclos/part16.htm

Van Dyke, J. M. (2005). An analysis of the Aegean disputes under international law. *Ocean Development & International Law*, *36*(1), 63–117. doi:10.1080/00908320590909088

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California