BEACH CARRYING CAPACITY ASSESSMENT: CASE STUDY FOR SUSTAINABLE USE OF KUSADASI BEACHES

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ABSTRACT

BEACH CARRYING CAPACITY ASSESSMENT: CASE STUDY FOR SUSTAINABLE USE OF KUSADASI BEACHES

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Intense and uncontrolled touristic activities have the potential to disrupt natural environments, such as beaches with irreversible physical and environmental impacts. In addition, possible socio-economic losses could be expected if the quality of the visitation (e.g., crowding, physical comfort of the visitor related to climatic conditions) to these areas are not considered in the management. The concept of carrying capacity defines the degree of acceptable use of natural areas and resource values, considering their long-term preservation physically and socio-economically. Considering the value of the beaches of Turkey, it is important to determine their carrying capacities for their sustainable use and management.In this study, physical and real carrying capacities of urban beaches with uncontrolled use in Kuşadası and natural beaches of Dilek Peninsula-Büyük Menderes National Park are discussed by applying the Cifuentes (1992) method. The impacts of the factors affecting the number of tourists (climatic conditions and coastal erosion) over the years are investigated. Change in the beach carrying capacity due to climate change (sea level rise and temperature) is also assessed. Real carrying capacities of Kuşadası beaches are expected to decrease at least to half of the current capacities because of the significant loss of beach area with rising sea levels in the next 100 years. Kadınlar beach has a high risk of losing all of its capacity within 50 years. The sustainability of beach activities in Kuşadası will be affected by loss of beach area and consequently the loss of quality of the visit because of crowding. The results show that an effective solution needs to integrate both visitor management plans and shoreline management strategies for beach areas.

Keywords: Beach Carrying Capacity, Coastal Zone Management, Sustainable Tourism, Sea Level Rise, Shoreline Evolution

ÖZ

PLAJ TAŞIMA KAPASİTESİ DEĞERLENDİRİLMESİ: SÜRDÜRÜLEBİLİR KULLANIM İÇİN ÖRNEK ÇALIŞMA, KUŞADASI PLAJLARI

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Yoğun ve kontrolsüz turistik faaliyetler, geri dönüşü olmayan fiziksel ve çevresel etkileri ile plajlar gibi doğal ortamları bozma potansiyeline sahiptir. Ek olarak, bu alanlara yapılacak ziyaretin kalitesi (örneğin, kalabalık, iklim koşullarıyla ilgili ziyaretçinin fiziksel rahatlığı) yönetimde dikkate alınmadığı takdirde olası sosyo-ekonomik zararlar beklenebilir. Taşıma kapasitesi kavramı, fiziksel ve sosyo-ekonomik olarak uzun süreli korunmalarını dikkate alarak doğal alanların ve kaynak değerlerinin kabul edilebilir kullanım derecesini tanımlar. Türkiye plajlarının değerini göz önünde bulundurarak, sürdürülebilir kullanımları ve yönetimleri için taşıma kapasitelerini belirlemek önemlidir.

Bu çalışmada, Cifuentes (1992) yöntemi kullanılarak, Kuşadasındaki kontrolsüz kullanımıyla kentsel plajların ve Dilek Yarımadası-Büyük Menderes Milli Parkdaki doğal plajların fiziksel ve gerçek taşıma kapasiteleri ele alınmıştır. Turist sayısını (iklim koşulları ve kıyı erozyonu) etkileyen faktörlerin yıllar içindeki etkileri incelenmiştir. Ayrıca, iklim değişikliğine (deniz seviyesinin yükselmesi ve sıcaklık) bağlı olarak plaj taşıma kapasitesindeki değişim değerlendirilmektedir. Kuşadası plajlarının gerçek taşıma kapasitelerinin, önümüzdeki 100 yıldaki yükselen deniz seviyesindeki ciddi plaj kaybı nedeniyle, mevcut kapasitelerin en az yarısına düşmesi beklenmektedir. Kadınlar plajının 50 yıl içerisinde tüm kapasitesini kaybetme riski yüksek. Kuşadasındaki plaj aktivitelerinin sürdürülebilirliği, plaj alanı kaybından ve buna bağlı olarak, kalabalıklaşma nedeniyle ziyaretin kalitesinin düşmesinden etkilenecektir. Sonuçlar, etkili bir çözümün hem ziyaretçi yönetimi planlarını hem de plaj alanları için kıyı yönetimi stratejilerini entegre etmesi gerektiğini göstermektedir.

Anahtar Kelimeler: Plaj Taşıma Kapasitesi, Kıyı Alanları Yönetimi, Sürdürülebilir Turizm, Deniz Seviyesi Yükselmesi, Kıyı Şeridi Erozyonu/ Birikimi

To my supportive parents & my guardian angel, Arian.

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LIST OF ABBREVIATIONS

ABBREVIATIONS

AutoCAD	Autodesk Computer-Aided Design
BCC	Beach Carrying Capacity
CCA	Carrying Capacity Assessment
CFSR	Climate Forecast System Reanalysis
DOC	Depth of Closure
DSAS	Digital Shoreline Analysis System
DTM	Digital Terrain Model
ECC	Effective Carrying Capacity
EPR	End Point Rate
EPR_{unc}	Uncertainty of End Point Rate
ESRI	Environmental Systems Research Institute
GEBCO	General Bathymetric Chart of the Oceans
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LRR	Linear Regression Rate
LTWS	Long-Term Wave Statistics
N	North
NASA	National Aeronautics and Space Administration
NNE	North North East

NNW	North North West
NSM	Net Shoreline Movement
NW	North West
PCC	Physical Carrying Capacity
RCC	Real Carrying Capacity
RCP	Representative Concentration Pathway
S	South
SCE	Shoreline Change Envelope
SDB	Satellite Derive Bathymetry
SLR	Sea Level Rise
SW	South West
SWAN	Simulating WAves Nearshore
SSW	South South West
TUİK	Turkish Statistics Institute (Türkiye İstatistik Kurumu)
UNEP	United Nations Environment Program
W	West
WLR	Weighted Linear Regression Rate
WNW	West North West
WSW	West South West
WTO	World Tourism Organization
WWF	World Wildlife Fund for Nature

LIST OF SYMBOLS

SYMBOLS	
A	Area
B	Berm/dune Height of the Active Beach Profile
C_f	Correction Factor
d_* or h_*	Vertical Dimension of Active Beach Profile
g	Gravitational Acceleration, 9.81 m/s^2
H_s	Significant Wave Height
$H_{s,0}$	Deep Water Significant Wave Height
L_0	Deep Water Wave Height
Mc	Management Capacity
M_T	Total Magnitude of Limiting Variable
Q	Exceedance Probability
R	Shoreline Retreat
R_f	Rotation Factor
S	Sea Level Rise
SLR	Sea Level Rise
T_s	Significant Wave Period
W_*	Horizontal Dimension of Active Beach Profile
Z	Visitor number
Δx	Sea Level Rise

CHAPTER 1

INTRODUCTION

The rapid development of various economical investments, touristic and recreational activities in coastal areas of Turkey have led the extreme increase in population density in these regions. The subsequent increase in demand for more areas to be used for touristic and recreational purposes exacerbate the disruption of these natural environments and coastal areas accompanying irreversible physical, environmental and socio-economic impacts and losses. The intensive tourism activities will cause unacceptable crowding and visitor conflicts and will reduce the quality of visitor's recreational experience over time. In particular, the excessive use of natural coastal areas can disturb fragile soils, vegetation and wildlife (Hammitt and Cole 1998; Manning 1999).

Beaches are especially used intensively in Turkey and around the world, as they are great source of income while providing recreation and relaxation (PAP/RAC 2005). However, lack of coastal zone management planning along with limited monitoring of the effects of natural processes such as coastal erosion, and social problems such as crowding, the sustainability of beach use has become a problem for most of the coasts of Turkey. Therefore, it is of importance to define the degree of acceptable use of these natural areas considering physical, environmental, economic and social dimensions. In addition, in order to prevent the implementation of inadequate or incorrect management strategies, it is essential to consider possible future changes such as shoreline evolution, sea level rise and climate change in the calculation of these acceptable visitor levels (Zacarias, Williams, and Newton 2011).

In light of these considerations, the aim of this thesis is to present the concept of beach carrying capacity and its assessment by adapting a commonly used carrying capacity assessment method of Cifuentes (1992) as a management tool for sustainability. This is achieved by;

- Calculating the maximum number of visitors that can physically fit in a defined beach area within a given time period considering influence of crowding on visitor comfort (Physical Carrying Capacity).
- Calculating maximum allowed number of visitors to a defined area after application of certain corrective factors to physical carrying capacity that restrict the use of the evaluated area throughout the year and to express the number of visitors in a more realistic way (Real Carrying Capacity).
- Integrating the effects of future threats such as climate change on beach carrying capacity by analyzing temperature rise projections and effect of future sea level rise on the shoreline erosion/accretion
- Highlighting possible management strategies for the selected beaches to ensure sustainability

The results of this study are expected to show an application of beach carrying capacity assessment and how integration of climate change impacts can be achieved with the methodology as a case study. It will contribute to a better understanding of the concept of integrated coastal zone management for beaches of Turkey as the analysis integrates not only physical but also social factors in the assessment. Finally, this study will demonstrate the capability of beach carrying capacity analysis to provide guidance in developing required strategies and implementing management plans to manage the tourism sector by securing high quality and quantity of coastal touristic areas.

In this study, literature on carrying capacity assessment focusing on tourism and coastal areas are summarized in Chapter 2. Selected applications to beaches around the world and in Turkey are also presented. The study area is introduced in Chapter 3 and main characteristics of beaches analyzed in this study are presented. The methodology used for beach carrying capacity assessment is presented in Chapter 4.

The application of one of the most preferable method for carrying capacity assessment of natural areas by Cifuentes (1992), are presented on some of beaches of Kuşadası with uncontrolled and intensive usage in this Chapter 5. In this Chapter, the results of the case study are presented, the implementation of the models used to evaluate the correction factors in assessment of beach carrying capacity are discussed and the assessment results are compared. Chapter 5 also discusses the impact of climate change and sea level rise on the carrying capacity of Kuşadası beaches. Finally, in Chapter 6, a summary of the study is presented together with recommendations for further studies to develop the beach carrying capacity analysis model.

CHAPTER 2

LITERATURE SURVEY

2.1. Concept of Tourism Carrying Capacity

According to Özkan (2001) (as cited in Attalah 2015), with the transition from agricultural society to industrial society in Europe since the beginning of the 20th century, people began to live in urban-industrial ecosystems, which have been deteriorating day by day. The concept of recreation has appeared and needs for recreational areas have increased ever since people started to lose the areas-where they used to live together and do their farming- for their recreational needs without even noticing the irreversible environmental impacts of these actions. With increasing urbanization (especially increase in transportation opportunities), income rates and development of conscious lifestyles with leisure and recreation being more dominant than before, the visitor densities and touristic activities in natural, cultural, recreational and/or protected areas known as recreation source have been increasing with a high acceleration according to Karaküçük (1999) (as cited in Attalah 2015). This change is deteriorating these sources, increasing the probability of environmental hazards (Attalah 2015), and decreasing the quality of natural (mostly non-renewable) resources, recreational experience and economic benefits. Impacts of tourism activities can be defined as two main categories presented as (Castellani and Sala 2012);

1. Impacts of structures for touristic purposes as hotels, camping sites, restaurants, etc. which are;
    - Loss of soil which is required for agriculture and other similar activities.
    - Over-consumption of resources.

- Need for more urbanization to meet the needs of increased level of tourists (new structures, roads and etc.).
- Pollution (Water, soil and air pollution).

2. Impacts due to the touristic activities in the recreation area which are;
    - Increase in wastewater and solid waste production which requires costly collection and disposal systems.
    - Possible conflictions between residents and tourists over local resource and service uses.
    - Crowding, traffic, noise pollution, disturbance to environment and wildlife as a result of increase in number of visitors.

At this point, the most fundamental question is that; "*how much can we use the environment without spoiling what we find most valuable about it?*" (Manning 2007). In 1987, the broad sustainable development framework was built to ensure the separation of economic and social growth from natural environment, wildlife and natural resources' depletion while developing long-term tourism and satisfying tourist's needs. The aim of sustainable development framework is meeting future generations' needs and maintaining economic, cultural, social and environmental sustainability principles as it is also stated by international and European resolutions such as United Nations Environment Program, International Union for Conservation of Nature, World Wildlife Fund for Nature and World Tourism Organization in the "Reviewed Strategy for Sustainable Development", the "Integrated Product Policy", the "National Action Plan on the Sustainable Consumption and Production", "Sustainable Industrial Policy" and the "Renewed European Union Tourism Policy" (Attalah 2015; Castellani and Sala 2012; Jurincic 2005; Zacarias 2010). According to Manning (1998), the building blocks of this framework are presented in the following Figure 2.1 stated in "Tourism Carrying Capacity Assessment Thesis" by Zacarias (2010).

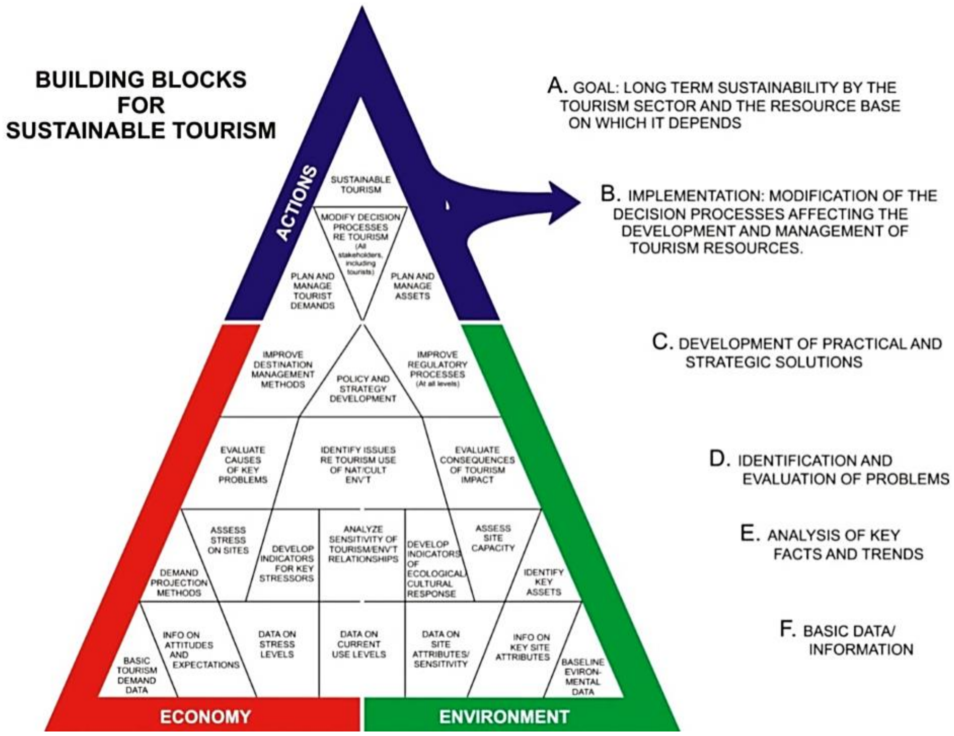

Figure 2.1 Sustainable tourism development (patterns, steps and issues) according to Manning (1998) (as cited in Zacarias 2010).

Based on this model developed by Manning (1998), in order to assess the goal of sustainable tourism development, an efficient and appropriate management planning of tourists and touristic destinations are required which is possible by adaptation of environmental-friendly policies and strategies. For the implementation of the most appropriate strategies and policies, data information related to the level and type of visitors, their values, attitudes and perceptions and major thresholds threatening the environmental values of the touristic destination are required (Zacarias 2010).

In order to manage and control tourism, identify and measure the impacts of recreational activities and set standards for acceptable changes in sensitive natural environments, various frameworks have been developed using qualitative methodologies such as;

- *Limits of Acceptable Change (LAC):* The maximum level of use that an area or resource can sustain before deterioration occurs (Manning 2002; Göktuğ et al. 2013).
- *Visitor Impact Management (VIM):* This tool covers a range of processes and techniques to manage and control visitors, their activities and their impacts in a given environment through sustainable use goals (Mejía, Carvajal, and Patiño 2001).
- *Visitor Experience Resource Projection (VERP):* It is designed by the US National Park Service General Management as a part of planning processes. In this management planning tool, the standards and indicators defining the appropriate levels of use are developed considering the resource quality and visitor experience quality and the desired situation in the future (Manning 2002; Göktuğ et al. 2013).
- *Management Process for Visitor Activities (VAMP):* This model was developed by Graham et al. (1988) within the Canadians Park Management Planning System. According to Nilsen and Tayler (1997) the basic principles of VAMP are implementation policies guide, management plan guide and visitor activity guide (Manning 2002; Göktuğ et al. 2013).
- *Recreation Opportunity Spectrum (ROS):* Developed by employees of the US Forest Service and Area Management Office, ROS is defined as a regional recreation planning tool to help managers and planners create inventory, to design target management standards, to decide between alternative management activities and to provide a wider context for planning recreation resources for multiple uses based on a comprehensive and integrated natural resource planning approach (Manning 2002; Göktuğ et al. 2013).

According to Kostopoulo and Kyritsis (2016), while having their own unique origin for making tourism sustainable with various management strategies and monitoring methods, all these frameworks were developed with the idea of “Tourism Carrying

Capacity” remaining as an integral part of the management framework (Attalah 2015). Despite its complexity and variability of its dimensions in the field of tourism, Carrying Capacity Assessment (CCA) is a powerful and efficient management and planning tool assuring a sustainable developed tourism, management of tourism flows to a touristic destination and detection of degree of negative impacts and intensity of use in these areas. (Ceballos-Luscarain 1996; Coccossis and Mexa 2004; Mondal 2012)

The most commonly used forms of carrying capacity concept in tourism are (Manning 2002; Da Silva 2002; Zacarias 2010; Rajan, Varghese, and Pradeepkumar 2013; Göktuğ et al. 2013; Kostopoulou and Kyritsis 2016);

1. *Physical Carrying Capacity*: the optimum number of tourists that can fit physically into a specified touristic area, beyond which environmental changes and irreversible negative impacts could occur.

2. *Economic Carrying Capacity*: the maximum level of touristic functions a touristic destination can accommodate without causing unacceptable changes within the local economy of that specified destination.

3. *Social (Socio-cultural) Carrying Capacity*: the optimum number of tourists in a touristic destination beyond which there may be conflicts between tourists with each other (density tolerance rate of tourists) or/and between tourists and host societies. This type of carrying capacity mainly describes and measures the users’ perception of different crowding levels in a touristic destination.

4. *Biophysical Carrying Capacity*: the maximum level of touristic functions and tourist numbers above which the natural environment (habitat) is not able to regenerate.

5. *Environmental (Physico-ecological) Carrying Capacity*: the maximum level of tourism above which the physical and ecological structure of the ecosystem

of the recreation area may change (erosion, soil compaction, vegetation loss and etc.).

6. *Psychological (conceptual) Carrying Capacity*: the maximum number of tourists that are all satisfied from their experience of recreation in a specified touristic destination.
7. *Institutional Carrying Capacity*: the maximum capacity of the governance system (governments, NGO’s and market sector) to alleviate the negative impacts of tourism.

2.1.1. Recreational Carrying Capacity in Natural and Protected Areas

The term “Carrying Capacity” in natural areas was first used in the literature by Hadwen and Palmer in 1922 (as cited in McCool and Lime 2001) which involves the concept of recreation and recreational carrying capacity as well as the management of wildlife and environmental resources (Clarke 2002). WTO has defined recreational carrying capacity in 1994 as the optimum number of people visiting a touristic area at the same time, without having physical, economic, socio-cultural and environmental deterioration and an unacceptable decrease in the quality of visitors’ satisfaction which can be calculated using various mathematical formulas (WTO 1981; Hens 1998; Munar 2002; Nghi et al. 2007).

Recreational carrying capacity generally refers to the amount and type of visitor use that is considered appropriate for the site without unacceptable degradation of the biological and cultural values of the recreational area (Manning and Lawson 2002). CCA is a method that allows us to make rules and decisions about the acceptable level of recreational activities in protected areas and national parks and about the extent to which the recreational use of these sources can be managed (Cole 2004). The concept of park management was first developed by Sumner for the Sequoia and Yosemite National Parks in United States of America in 1936 (Sumner 1936). Yet, the comprehensive work of recreational CCA of national parks and protected areas were emerged in 1960 at first and has been developed in the last 50 years in order to maintain the balance between protection, usage and sustainability of natural areas (McCool and Lime 2001; Manning 2002; Göktuğ et al. 2013). Furthermore, with participation of 14 Mediterranean countries for the last 17 years, it was decided that CCA of natural and protected areas (especially coastal areas), is an efficient and effective planning method to be implemented in both less developed and developed regions (UNEP/PAP 1997; Klaric et al. 1999).

There are many studies considering different aspects and dimensions of carrying capacities in natural areas as National Parks and protected areas (Cifuentes Aries et al. 1999; Papageorgiou and Brotherton 1999; Lawson et al. 2003; Nghi et al. 2007; Yüksel et al. 2008) (as cited in Göktuğ et al. 2013). The most widely used method for CCA in natural and/or protected areas is the Cifuentes (1992) methodology for estimating protected areas' carrying capacity. Cifuentes's methodology (1992) considers the effects of site-specific factors and limitations of the touristic destination on reduction of the level and quality of visitation. The Cifuentes's CCA of natural and protected areas is suggested by International Union for Conservation of Nature (IUCN) which is further explained and applied in different fields by other reasearchers such as; Amador (1996), Ceballos-Lascuráin (1996), Munar (2002), Nghi et al. (2007), Segrado et al. (2008) and Zacarias et al. (2011) (as cited in Attalah 2015; Sayan and Atık 2011).

The six steps of estimation of recreational carrying capacity of protected areas according to Cifuentes (1992) are as follows;

I. Analysis of tourism and protected area management policies of protected areas and tourism responds to needs of two mainly independent environment and tourism sectors by identification of the gaps of local, regional and national policies.

II. Analysis of objectives of the protected area regarding the public use and acceptability of levels of current recreational and touristic activities.

III. Examination of the zoning of the protected area and analysis of current visitation regarding the definition of a zone or zones for extensive or intensive use by visitors.

IV. Definition, strengthening or modification of policies regarding management categories and zoning regarding the definition and suggestion of new policies and/or modification of existing ones for any possible conflicts in present and/or future or even complete replacement of a new management tool on restricting the usage or in extreme cases, define prohibition policies.

V. Detailed identification of site-specific factors and characteristics, natural resources and the level of fragility and vulnerability of each site that influence that public-use site or protected area. The main factors defined by Cifuentes (1992) influencing the carrying capacity of protected areas are as biophysical, ecological, social and management factors. For instance, seasonal climate conditions and unexpected hazards may reduce the attraction of the site, the type of topography and wave characteristics of that area may support erosion or accretion which will directly limit/increase the visitor access and density.

VI. Determination of the carrying capacity of each public-use site by Cifuentes (1992) method to define the maximum number of visitors that a specific protected area can tolerate as three main dimensions of following carrying capacities (Cifuentes 1992);

    i. Physical Carrying Capacity (PCC)
    ii. Real Carrying Capacity (RCC)
    iii. Effective or Permissible Carrying Capacity (ECC)

Based on the framework defined by Cifuentes (1992), the carrying capacities of protected areas and natural sites are defined in 3 main dimensions (physical, real and effective) considering the site-specific characteristics which may limit the usage of that area and reduce the level and quality of visitation (Figure 2.2) (Cifuentes 1992).

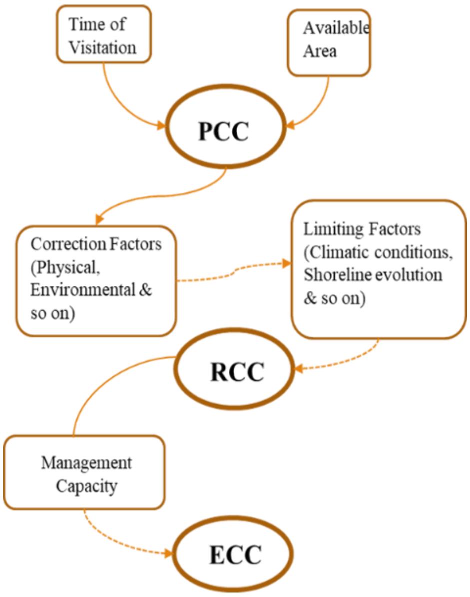

Figure 2.2 Cifuentes (1992) Carrying Capacity Dimensions

The dimensions in this method are based on the parameters related to the physical characteristics of the area and management opportunities of the site. Although the method does not include ecological and social parameters, it is one of the most effective and widely used methods in estimation of the physical and real carrying capacities of different touristic sites around the world. Some noteworthy examples of the studies in which Cifuentes (1992) is adapted and applied are for carrying capacity estimation of beaches (Zacarias et al. 2011; Rajan et al. 2013), eco-sensitive areas or protected areas (Kostopoulou and Kyritsis 2006; Sayan and Ortaçeşme 2006; Kurhade 2013), forests (Lagmoj et al. 2013); museums (Mondal 2012), caves (Nghi et al. 2007) and lagoons (Fadaee et al. 2013) (as cited in Attalah 2015).

2.1.2. Recreational CCA of Coastal Areas

One of the most important natural resources used for recreational activities are coastal areas. A great percentage of tourism sector are attracted towards coastal areas since 19th century. As globalization continues, beaches around the world are becoming more crowded with increasing threats to local ecosystems, environmental degradation and local cultural heritage loss which arise a need for a proper resource management practice. Based on the assumption that increased tourism development, especially in coastal regions, may hinder the sustainability of coastal natural resources and reduce their value for recreational activities, the assessment of tourism carrying capacity has become an important step in worldwide studies ensuring the long-term sustainability of touristic, natural and/or protected coastal areas.

When the articles related to the calculation of the carrying capacity are reviewed, it is seen that the carrying capacity of the beaches are evaluated with different strategies. In most of these studies natural and anthropogenic physical changes in beaches are not considered in CCA at the same time. Evaluation of these natural and anthropogenic impacts caused by site-specofic conditions and/or as a result of excessive beach use over time, will help us to make the necessary management planning in more comprehensive and efficient ways possible (Simeone, Palombo, and Guala 2012).

Furthermore, in most of the studies related to estimation of carrying capacity such as Zacarias et al. (2011), Rajan et al. (2013), Kostopoulou and Kyritsis (2006), Sayan and Ortaçeşme (2006) and Kurhade (2013) (as cited in Attalah 2015), it is seen that the analysis of physical and climatic variations and their impacts on the beaches is done mostly according to past and present conditions; however, in order to ensure the sustainable use of beaches and to prevent the implementation of inadequate or incorrect management strategies, it is essential to consider possible future changes in the calculation of these corrective factors (coastal erosion, climatic and weather conditions, sea level rise, etc.) (Zacarias et al. 2011). Also, for the determination of the type and intensity of beach use, the evaluation of users' perceptions about recreational usage of beaches and assessment of their knowledge or perceptions about physical, social and environmental issues on the site could be helpful in recreational capacity analysis; thus, it will help to identify the legislation and rules that beach users must comply with for sustainable use (Khamis, Kalliola, and Käyhkö 2017).

Some noteworthy examples of CCA in which the effects of natural and/or anthropogenic impacts are analyzed are based on the methodology of Cifuentes (1992) applied to coastal areas as;

- CCA of an island in India (Bera, Das Majumdar, and Paul 2015) by measuring physical, real and effective carrying capacities considering the specific limitations of the area (such as; rainfall, excessive sunshine, cyclone and beach quality) and management capacity factors (such as; available infrastructure, facilities, staff capacity and budget and amenities).

- CCA of three estuarine beaches (Colares, Maruda and Murubira) on the Amazon coast of Brazil through the application of recreational carrying capacity indices of water, environmental and ecological qualities and quality of services. (Sousa et al. 2014)

- CCA of a beach in coastal city of Monte Hermoso in Argentina measuring physical, real and effective carrying capacities considering the corrective factors of rainfall, strong winds, sunshine, temporary closure periods and beach erosion. The management capacity factors used in this study are (Huamantinco et al. 2016);

    - Institutional support (information services, access regulation & so on.)
    - Services (tent rental, restaurants and drugstore)
    - Personnel (lifeguards and people trained for natural disaster response)
    - Infrastructure (bathrooms, coastal buildings, beach access & so on.)

- CCA studies in Emilia-Romagna in Italy assessing the relationship of physical and geomorphological characteristics of the beaches, beach carrying capacity (BCC) and users' perception based on two methods of Cifuentes (1992) and Williams and Micallef (2009). The corrective parameters used in this study are erosion, precipitation and accessibility factors (limiting tourist activity) (Rodella et al. 2017).

Another methodology used as a conceptual model applicable in most of the tourism areas is based on a DPSIR model (Drivers, Pressure, State, Impacts & Responses) which is mainly focused on pressures on environment, ecosystem and human health and management issues related to local policies (Sousa-felix, Cajueiro, and Pereira 2017). Due to limitations of this model, it is not suggested to be used in most of the studies. Some of these limitations are; not having a clear cause & effect relationship, reliability on only static indicators and not considering dynamic of ecology and society and not having a clear boundry between ecosystem state and human impact (Gari 2015).

2.1.2.1. Recreation CCA of beaches in Turkey

Large proportions of various touristic and economical activities in Turkey have been moved to marine and coastal regions in the last 50 years according to the Mediterranean Action Plan (PAP/RAC 2005). The increase in the number of tourists and the demand for areas suitable for recreational activities and tourism, has led to a significant increase in visitor density at these natural areas that should be in protection. Lack of adequate coastal zone management planning regarding the monitoring of negative effects of physical processes as extreme beach usage, natural processes as the climate change and resulting sea level rise, air temperature increase and shoreline evolution, has become a problem for most of the coasts of Turkey which is mandatory for analysis of physical, environmental and socio-economic returns (PAP/RAC 2005).

Two of the studies related to CCA in Turkey were determination of yacht carrying capacity of Fethiye-Göcek by METU Coastal Engineering Laboratory in 2007 and by Dzabic (2012) in order to determine the level of damages to ecosystem, air, water, noise and aesthetic pollution, the level of water resource and land loss. The need for changes in management policies and regulations were discussed based on the results of this study (Yalçıner and Ergin 2007; Dzabic 2012).

Another study emphasizing the importance of carrying capacity in tourism is the "Attitude of local people about the environmental impacts of tourism" by Dal (2008) in which the recreational use of coastal areas in Kuşadası is discussed. In this study, a questionnaire has developed and applied to 125 local people living in Kuşadası to collect information about the local people's perception regarding the environmental impacts of tourism on coastal land use and according to the results, some suggestions have been made for the proper land use in Kuşadası and to maintain a sustainable tourism in this region.

Another study regarding the definition of recreational carrying capacity, it's dimensions and visitor management models is the "Theory of Carrying Capacity in National Parks-Development and Modeling Processes" by Göktuğ et al. (2013). In 2011, Göktuğ has studied the determination of recreational carrying capacity in Dilek Peninsula National Park of Kuşadası in his doctoral thesis. In this study the physical, real, effective, social and ecological carrying capacities of recreational areas in the National Park were determined between years of 2009 and 2011. The results of this stdy showed that excessive use of Kalamaki Bays have caused ecological degenerations to some degree (Göktuğ 2011).

Moreover, the recreational carrying capacity assessment of a National Park in southern Turkey, Termessos, is a notable study which estimates the optimum level for recreation used of this protected area by using the Cifuentes (1992) methodology considering the limiting bio-physical, ecological and managerial characteristics of the area. Also, in this study, on-site questionnaires were conducted in order to collect information and data about demographic and visit characteristics of National Park users (Sayan and Atık 2011).

In 12th National Tourism Congress proceedings book, a study about determination of approach of people in İğneada to eco-tourism is conducted by Küçükaltan and Yılmaz (2011). In this study, the recreational carrying capacity of Erikli, Limanköy and Beğendik beaches are measured based on the Cifuentes (1992) methodology in the context of sustainable tourism and conservation of Longoz forests, Lagün lakes, endemic plants, flora and fauna of İğneada.

Moreover, in “Eymir: Araştırmalar, Proje ve Planlama Çalışmaları”, which includes some of the plans, projects and researchs drawn on Lake Eymir and its surroundings, the social carrying capacity assessment of Eymir on ensuring the sustainability of this protected area was discussed and analyzed by Tarakcioğlu and Khodkar (2017). Analysis of social carrying capacity of Eymir helps to ensure the sustainability of this protected area and preservation of the natural and cultural values in this area without decreasing the recreational experience of users (Bütüner and Keskinok 2018).

Two of the recent studies on evaluation of recreational carrying capacity are firstly, the carrying capacity assessment of Beyşehir Lake National Park which was conducted by Göktuğ and Arpa (2016) in order to ensure sustainability of boat tours organized in this lake. In this study, physical, real and effective carrying capacities of Beyşehir Lake are calculated and based on the results of this study, recommendations were made to ensure ecological and economic sustainability. Secondly, the recreational canoe carrying capacity of Lake Mert-National Park, İğneada was assessed by Dumlu and İhtiyar (2017) as physical, real and effective capacities in order to be able to offer planning and management suggestions related with ecological and economic sustainability of National Park.

Based on the studies of carrying capacity assessment in Turkey that have been reviewed in the literature, this study is the first to evaluate and analyze the carrying capacities of a touristic site considering both current and future limiting factors and impacts.

CHAPTER 3

STUDY AREA AND DATA

3.1. Study Area

Kuşadası is a district of Aydın province in the Aegean region. It's rich history and natural beauties make Kuşadası one of the popular tourism centers in Turkey. It is also one of the most important touristic cruise destinations in the Mediterranean, where many historical and sacred sites such as Ephesus, Temple of Artemis, house of St. Mary, St. John's Basilica and Claros are nearby. Being one of Turkey's most important tourism centers, its indigenous population is approaching to 2 million with the increase in the number of foreign and local tourists in the summer months. In 2018, people who came to the region without reservations and could not find a place to stay despite the warnings, have found the solution in setting up tents on public beaches and some have chosen to stay in parks (tvDEN Newsletter 2018). The president of Kuşadası Tourism Foundation stated that Kuşadası were experiencing one of its busiest periods of the last years (Figure 3.1).

Figure 3.1 Kadınlar beach on 19th August 2018 (10:55), (tvDEN Newsletter 2018)

The distance of Kuşadası to Aydın center is 71 km. Kuşadası is also 90 km far from Izmir, 21 km from Selçuk and 157 km from Bodrum and Çeşme. So, it is one of the most preferred regions for tourism, hotels and summer vacation houses in the Aegean region with its blue flag, long and mostly with free entrance beaches offering a comfortable holiday opportunity for its visitors. Total bed capacity in Kuşadası district was 42,875 in 2017 (Ministry of Environment and Urbanization 2017).

Although the number of tourists coming to the district has reached an important level to make a significant contribution to the economy, all of the tourism activities do not overlap with the principles of sustainable tourism. The sustainable use of the limited and historical resources in the region is extremely important for the development of regional economy. Therefore, long term sustainable tourism policies should be developed in order to prevent increase in population and construction market due to unplanned tourism demand and irreversible environmental problems.

According to the population statistics of Aydın/ Kuşadası district center retrieved from TUIK (Turkey Statistical Institute), the annual population growth of Kuşadası for 2018 is 4% with total population of 113580 (TUIK 2019). The study area consists of eight beaches in Kuşadası area which are shown in Figure 3.2.

Figure 3.2 Kuşadası beaches (Google Earth)

In this study, analysis and results for four different types of urban and non-urban (natural) beaches with intensive use and four natural beaches with restricted use are presented.

Kadınlar- is located close to the center of Kuşadası and took this name because it was used only by women during the Ottoman period. Nowadays, it is a public beach and you can enter this beach without paying any fee. With its sandy beach, this area is a suitable option, especially for those looking for a place with rich natural landscape if the intense summer population increase is not considered. The sea of this beach is quite mossy which is not very pleasant. Yet, it is usually calm in summer months which makes it suitable and safe recreational activities.

Güzelçamlı- is one of the most preferred beaches in Kuşadası as well as Kadınlar beach. This area, which is full of beautiful natural sceneries and historical structures, is one of the places to visit. Güzelçamlı has a sandy beach and the sea is clear and clean. It is indicated as one of the addresses that should be examined directly, especially for those seeking a clean sea. This region, which has a high human density in the summer, is still well maintained. The depth of the sea is moderate. It is shown as one of the ideal places for vacation with the family, particularly. The sea water temperature rises to about 26°C in July (Yılmaz 2019).

Davutlar- is located 4 km from the center and it is one of the most visited places in Kuşadası. The long and wide coastline of approximately 12 kilometers makes this region unique. This region, which has been gaining popularity since 1980s, has been shown as one of the most explored locations for holidays (Yılmaz 2019). Having a shallow sea, Davutlar is not the most ideal option for those who want to use water depth as a preference. It is more suitable for those who wants a beach with fine sand and with its blue flag, it is shown as one of the most ideal seas for swimming. On the other hand, it should be noted that in Davutlar, usually higher waves are observed when it is compared to other beaches of Kuşadası. Especially for those who take this option seriously, Davutlar may be a disadvantageous option.

Pamucak- is one of the areas relatively far from the center and its beach is considered as one of the most ideal places to swim. Pamucak, which is a more ideal option especially for those looking for a quiet and peaceful region, is a unique choice in Kuşadası. It will be suitable for a quieter holiday with its unique structures, high quality hotels, restaurants and other facilities. To get away from the noise of the city for a moment and spend a more peaceful time in Kuşadası, Pamucak stands out as a more convenient option than other beaches (Yılmaz 2019). With its calm water and soft and fine sandy beach, Pamucak welcomes a small number of visitors in a quite large area. Unlike other regions, even in the summer, it is shown as one of the beaches where visitors do not flock heavily.

Bays of Dilek Peninsula National Park- which is known as Dilek Peninsula Büyük Menderes Delta, are located at the last point where Dilek Mountain extends to the Aegean Sea within Aydın province. Büyük Menderes Delta, located at the south of the peninsula, constitutes a biodiversity where fresh and salty water mixes. This rich nature provides a shelter for a variety of animal species and there is a rich vegetation especially in the northern part. The bays of this National park where you can swim are known as *İçmeler, Aydınlık, Kavaklıburun* and *Karasu* beaches and their distances from national park entrance are 1 km, 5 km, 9 km and 11 km, respectively (Ministry of Forestry and Water Management 2017).

3.2. Data

The data used in the study is grouped into four sections: (1) coastal data including geomorphology, wind and wave climate and bathymetry; (2) climate data; (3) climate change projections and (4) field observations.

3.2.1. Coastal Data

Beach data is used to provide information to calculate the physical carrying capacity of each beach as well as to estimate the shoreline dynamics under present and future conditions. The data presented here are geomorphological characteristics of the beach and the available area for beach use, rotation factor of each beach and space required for each user for recreational use, bathymetry, and wind and wave climate.

3.2.1.1. Geomorphology and Beach Characteristics

In order to determine physical characteristics of the beach as well as to estimate shoreline dynamics the satellite images of the the beaches in Kuşadası were obtained from Google Earth for the years 2004, 2006, 2011, 2012, 2013, 2014, 2015, 2016, 2017 and 2018 covering nearly the last 15 years. The spatial resolution of the SPOT satellite sensors providing the images ranges between 2.5-5 meters until 2010 (SPOT-5) and 1.5 meters afterwards (SPOT-6 and 7) (Satellite Imaging Corporation 2017). To determine the available beach area and other beach dimensions, the most recent available image (2018) was used.

The main physical characteristics, beach type and soil types of these beaches are presented in Table 3.1. Physical dimensions of beaches (average width and length) are obtained from Google Earth satellite imagery by creating paths on maps and measure the distances. Soil types were investigated in the fields as either sand (rock fragments with diameter from 1/16 to 2 mm) or gravel (rock fragments with diameter higher than about 2 mm) according to Wentworth (1922) grain size classification (as cited in UCL 2019). The berm heights for each beach are measured from the elevation data obtained from EMODnet bathymetry and validated in the field observations.

Table 3.1 Beach Types & Their Physical Dimensions

Beach	*Beach Type*	*Soil Type*	*Average Width, m*	*Length, m*	*Berm Height, m*
Karasu*	Natural-restricted use	Gravel	18	460	2.5
Kavaklıburun*	Natural-restricted use	Gravel	7	942	1
Aydınlık*	Natural-restricted use	Gravel	18	747	0.5
İçmeler*	Natural-restricted use	Gravel	10	290	0.5
Güzelçamlı	Urban-intensive use	Sand	55	1780	1
Davutlar	Urban-intensive use	Sand	35	9114	2
Kadınlar	Urban-intensive use	Sand	20	645	0.5
Pamucak	Natural-intensive use	Sand	65	2088	1

*Beaches in Dilek Peninsula-Büyük Menderes Delta National Park

The total available area of the beaches for recreational use were obtained from Google Earth satellite imagery by creating polygon for each beach and measuring the area of the polygon by Google Earth given in Table 3.2.

Table 3.2 Available Areas of Beaches Obtained from Google Earth Satellite Imagery

Beach	*Total Available Area, m^2*
Karasu	7283
Kavaklıburun	7820
Aydınlık	11691
İçmeler	4221
Güzelçamlı	79540
Davutlar	242223
Kadınlar	9987
Pamucak	189185

For each beach Satellite images of the beaches are given in Figure 3.3 (Karasu), Figure 3.4 (Kalamaki), Figure 3.5 (Aydınlık), Figure 3.6 (İçmeler), Figure 3.7 (Güzelçamlı),

Figure 3.8 (Davutlar), Figure 3.9 (Kadınlar) and Figure 3.10 (Pamucak) (Google Earth 2019).

Figure 3.3 Satellite Imagery of Karasu (Google Earth 2019)

Figure 3.4 Satellite Imagery of Kavaklıburun (Kalamaki) (Google Earth 2019)

Figure 3.5 Satellite Imagery of Aydınlık (Google Earth 2019)

Figure 3.6 Satellite Imagery of İçmeler (Google Earth 2019)

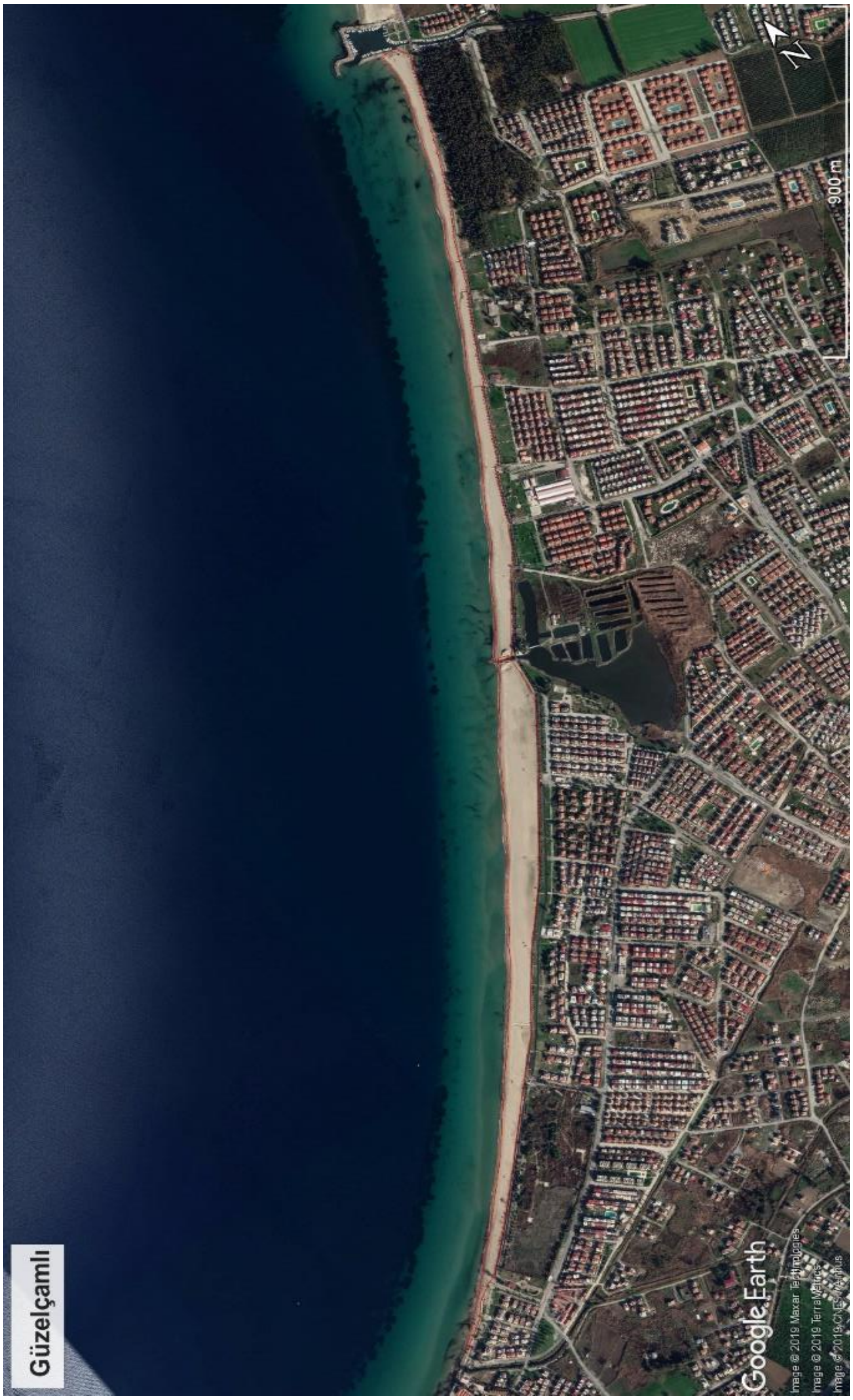

Figure 3.7 Satellite Imagery of Güzelçamlı (Google Earth 2019)

Figure 3.8 Satellite Imagery of Davutlar (Google Earth 2019)

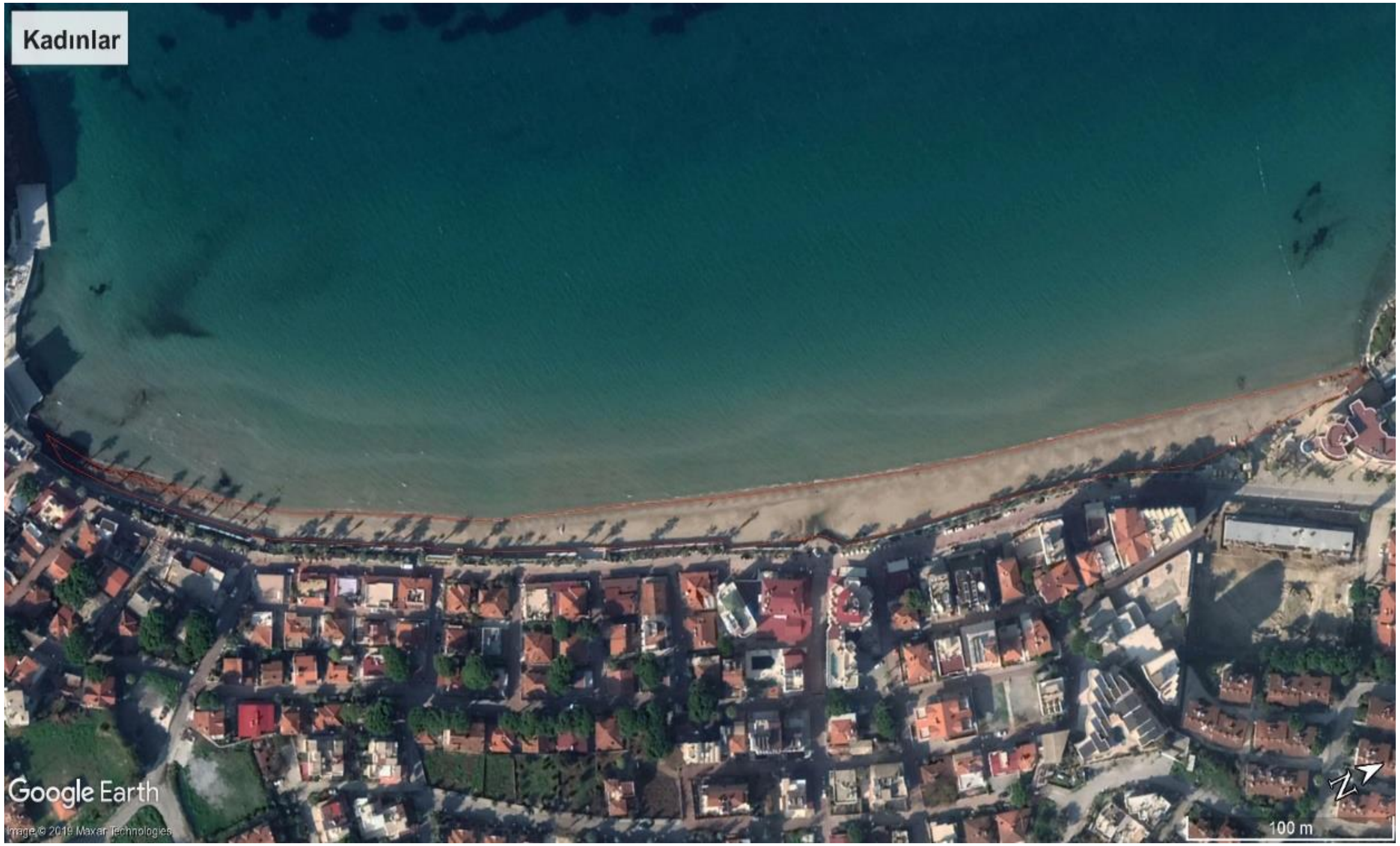

Figure 3.9 Satellite Imagery of Kadınlar (Google Earth 2019)

Figure 3.10 Satellite Imagery of Pamucak (Google Earth 2019)

3.2.1.2. Bathymetry

The bathymetry data of the study area were obtained from EMODnet Digital Terrain Model (DTM) with grid resolution of 1/16 x 1/16 arc minutes (circa 115 x 115 meters) which has been generated for European sea regions from selected bathymetric survey data sets, composite DTMs, Satellite Derive Bathymetry (SDB) data products where GEBCO Digital Bathymetry is used to complete the gaps with no data coverage (EMODnet Bathymetry 2019). For the study area, the bathymetry data is plotted as Figure 3.11 using Surfer-14.0.599 with 250 m resolution for coarse run and 50 m resolution for nested run. This data is used to determine beach profile and as input of SWAN model for wave transformation.

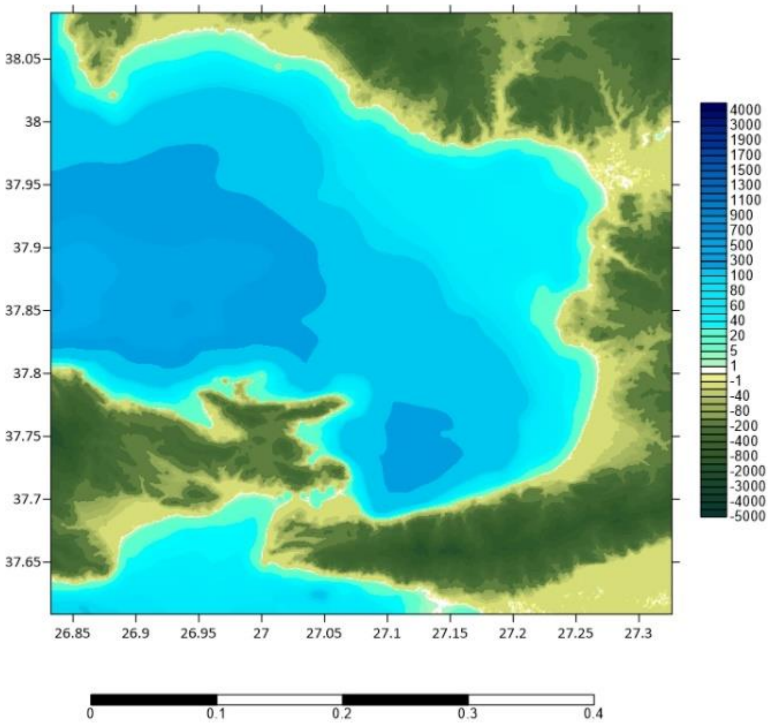

Figure 3.11 Bathymetry basemap of Kuşadası plotted with Surfer

3.2.1.3. Wind and Wave Climate Analysis

In order to determine the wind and wave characteristics in the study area, the hourly wind data of years between 1979-2018 were obtained from Climate Forecast System Reanalysis (CFSR), which is a third generation reanalysis product with one hour temporal resolution and T382 Gaussian grid spatial resolution to deliver wind speed as eastward (u) and northward (v) wind speed vectors at 10 meters above the surface (Climate Data Guide 2019). The wind dataset containing the nearest and appropriate point of the region (37.92° N-26.80° E for years 1979-2011 & 37.94° N-26.88° E for years 2011-2018) were examined to obtain annual and seasonal wind roses of the study area as presented in following Figures 3.12 and 3.13.

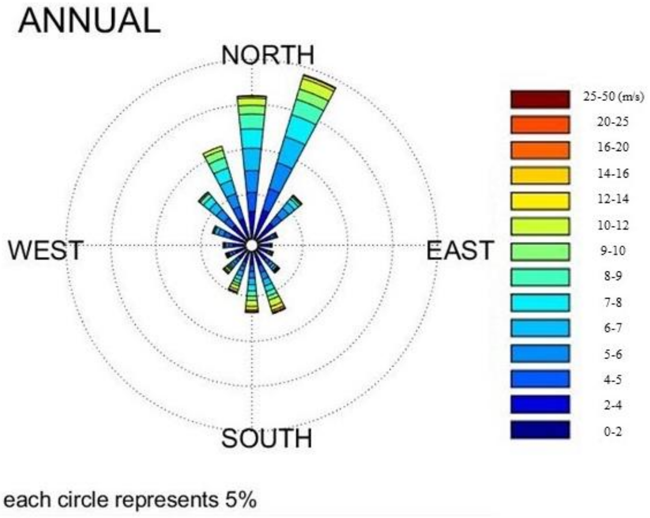

Figure 3.12 Annual windrose of the study area

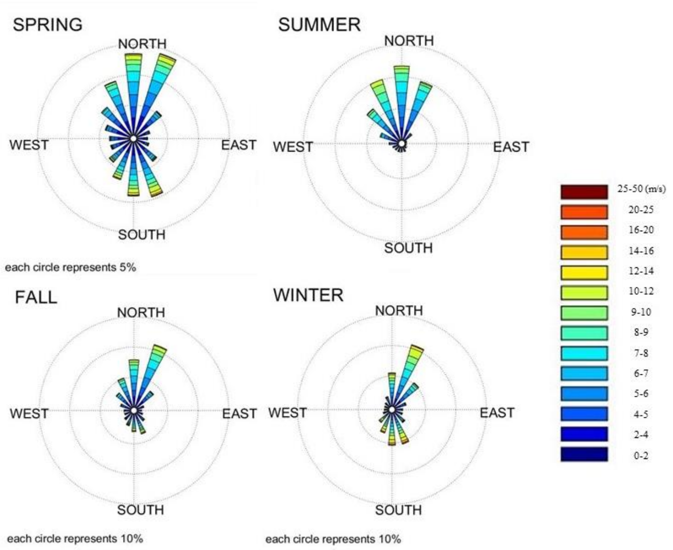

Figure 3.13 Seasonal windroses of the study area

As it is observed from the obtained windroses, the dominant wind directions are from N, NNE and NNW mainly with speeds between 6-10 m/s.

In addition to wind climate, wave climate studies of the study area were carried out using the same CFSR datasets for 37.92° N-26.80° E (1979-2011) & 37.94° N-26.88° E (2011-2018) points. For the estimation of effective fetch lengths used in the wave prediction studies, map of the study area was obtained from Google Earth and the fetch lengths for points 37.92° N-26.80° E and 37.94° N-26.88° E were drawn (7.5° intervals using AutoCAD as (Figure 3.14 as an example for one of the points) to calculate the effective fetch lengths as it is tabulated in Table 3.3.

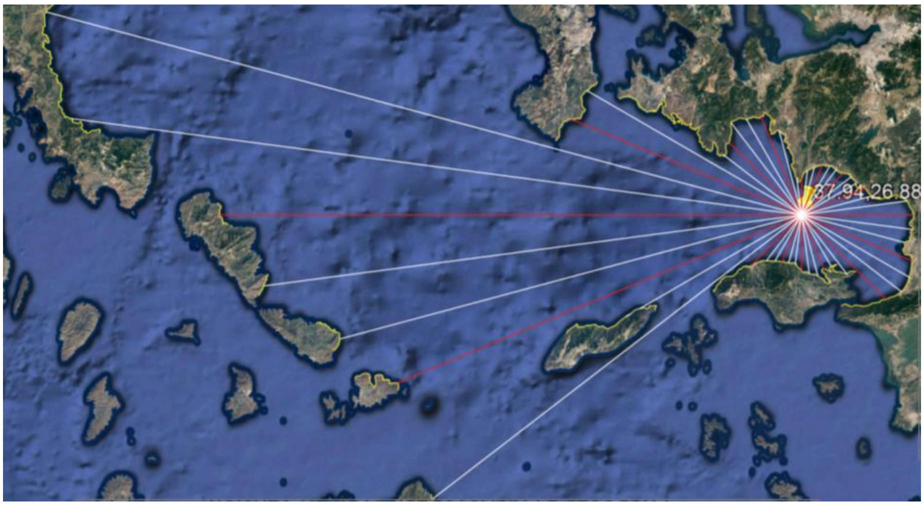

Figure 3.14 Fetch lengths of point 37.94° N-26.88° E using AutoCAD

Table 3.3 Effective fetch lengths (km) using AutoCAD

Direction	*Effective Fetch Length 37.92°N-26.8°E, km (AutoCAD)*	*Effective Fetch Length 37.94°N-26.88°E, km (AutoCAD)*
W	175.6	162.43
WNW	128.5	138.92
WSW	126.8	123.61
SW	60.4	77.26
NW	46.9	48.84
ESE	37.5	38.91
E	32.0	37.50
SE	31.3	32.98
NNW	27.4	31.78
ENE	24.9	31.33
SSE	22.3	27.24
NE	19.2	26.89
N	18.8	23.29
SSW	17.7	21.39
S	17.6	16.30
NNE	16.3	12.96

For determination of average hourly significant wave parameters, the deep-sea wave prediction mathematical model of “W61” modified by METU Coastal Engineering department is used. In this model, the average wave characteristics are obtained using the energy generation by the frictional force of the wind on the sea surface and its development over time (Ergin & Özhan 1986; Ergin et al. 2008; Ergin et al. 2009).

By using the hourly wind speed data and direction information provided from CFSR datasets and calculated fetch lengths from AutoCAD were used to determine the deep water significant wave heights ($H_{s,0}$) and significant wave periods (T_s) of wind waves occurring in all storms for years between 1979-2018. By using the obtained wave parameters, steepness (ratio of deep sea water significant wave height, $H_{s,0}$ to wave length, L_0) is obtained as 0.0461 for the region.

In order to determine the wave climate of the study area, long term wave statistics study was also conducted. Deep sea wave heights of these years were classified in 0.4 meters intervals and the frequency of the waves greater that the lower limit of each wave height range was obtained as presented in Appendix. By recording these times on a semi-log graph paper, the equation of the most appropriate line passing through these points are obtained using the following Equation 3.1.

$$Q(>H_{s0}) = \exp[(H_{s0}-B)/A] \tag{3.1}$$

Where, $Q(>H_{s,0})$ gives the total exceedance probability of a given $H_{s,0}$ and the coefficients A and B correspond to the slope and intercept of the line that best fits the wave heights and the total exceedance probability values, respectively. Total exceedance probability curves are given in Figure 3.15 and the information regarding $H_{s,0}$ values from the effective fetch directions for different exceeding probabilities are tabulated in Table 3.4.

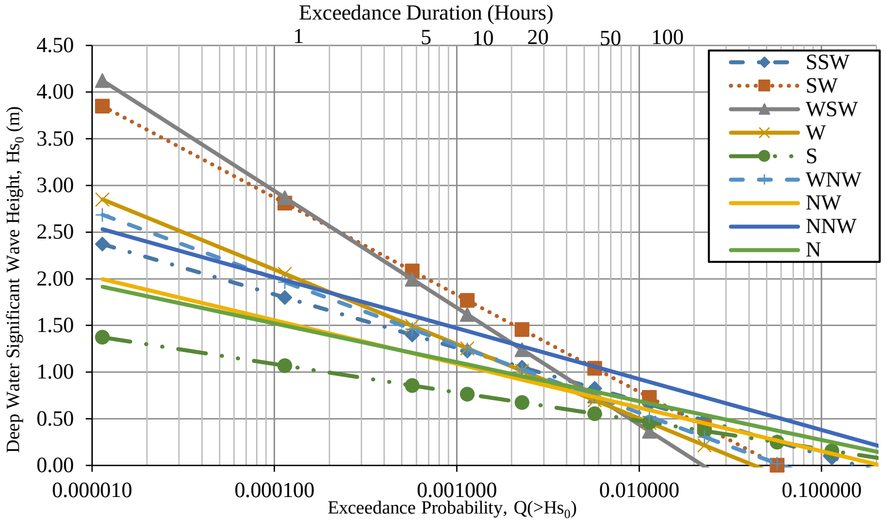

Figure 3.15 Graph of Long-Term Wave Statistics (LTWS)

Table 3.4 Deep water significant wave height (m) and wave period (s) values

Exceeded hours/year	*parameter*	*S*	*SSW*	*SW*	*WSW*	*W*	*WNW*	*NW*	*NNW*	*N*
1	H_{s0} (m)	1.07	1.80	2.81	2.87	2.05	1.96	1.53	1.99	1.50
	T_s (sec)	3.86	5.00	6.25	6.32	5.35	5.23	4.61	5.26	4.57
10	H_{s0}	0.77	1.23	1.77	1.62	1.25	1.24	1.06	1.44	1.08
	T_s	3.26	4.13	4.96	4.75	4.18	4.16	3.84	4.48	3.88
12	H_{s0}	0.74	1.18	1.69	1.52	1.19	1.19	1.02	1.4	1.05
	T_s	3.21	4.05	4.85	4.60	4.07	4.06	3.77	4.41	3.82
50	H_{s0}	0.55	0.83	1.04	0.74	0.70	0.74	0.73	1.06	0.79
	T_s	2.77	3.39	3.81	3.21	3.12	3.21	3.20	3.84	3.32
100	H_{s0}	0.46	0.65	0.73	0.36	0.46	0.52	0.59	0.89	0.67
	T_s	2.54	3.02	3.18	2.25	2.52	2.70	2.87	3.53	3.04

3.2.2. Climate Data for Kusadasi

Based on the population statistics of Kuşadası region mentioned in Statistical Institution of Turkey and Kuşadası zoning plan report (TUIK 2019; Ministry of Environment and Urbanization 2017), it is assumed that the most preferable period for recreational visits in Kuşadası is between May-October months. In this period, the climatic conditions are the most preferable for recreational use in this region. In addition to the climatic conditions, school holidays and national holidays makes a great contribution in increasing crowding densities in hotels and private villages in Kuşadası. So, the data of May-October months are used to determine the correction factors and limiting characteristics of beaches.

The following climate parameters are used in this study as correction factors:

- Air Temperature (Excessive Sunshine)
- Precipitation
- Snowfall
- Wind Speed
- Total Cloud Cover

Sea water temperature conditions is not considered as a correction factor since that in Kuşadası sea water temperature is between 22-28°C for the period considered in this assessment and according to Güçlü (2010) (as cited in Göktuğ 2011), it is reported that the most suitable period for sea bathing is when sea water temperature is between 20-32°C.

Required data for the climate correction factors as temperature at 2 meters above earth surface (K), total cloud cover (0-1), total precipitation (m/hour), snowfall (m of water equivalent), 10 m horizontal and vertical components of wind (m/s) were extracted from Copernicus climate data store as ERA5 hourly datasets on single levels from 1979 to 2018. “ERA5 is the fifth generation ECMWF atmospheric reanalysis of the global climate which combines model data with observations from across the world into a globally complete and consistent dataset using physics laws” (Climate Change

Service 2019). The mentioned datasets with GRIB file format were collected from ERA5 for coordinates of 37° 45’ 0” N, 27° 15’ 0” E and then organized using MATLAB to obtain the correction factors as percentages of restricted hours. The horizontal resolution of ERA5 hourly estimate data is available on regular latitude-longitude grids at 0.25° x 0.25° resolution. The obtained datasets for coordinates of 37° 45’ 0” N, 27° 15’ 0” E are assumed as valid for all beaches of the study area. The variables were downloaded using following grib formats;

- *Horizontal component of wind*: ‘10m_u_component_of_wind’
- *Vertical component of wind*: ‘10m_v_component_of_wind’
- *Temperature*: ‘2m_temperature’
- *Cloud cover*: ‘total_cloud_cover’
- *Snowfall*: ‘snowfall’
- *Rainfall*: ‘total_precipitation’

3.2.3. Climate Change Projections

Changes in temperature and precipitation as well as the impact of sea level rise are integrated into RCC calculations to determine the possible changes to RCC because of climate change. In this section, the data used in temperature, precipitation and sea level rise projections is presented.

3.2.3.1. Temperature Projections

The climate change and accompanying temperature increase will disrupt the comfort of users and limit the beach usage. Therefore, the temperature correction factors are calculated using the RCP 4.5 and RCP 8.5 projections for 2016-2100 years with specified intervals presented in Table 3.5 to include the effect of temperature increase in the region (Demircan et al. 2017).

Table 3.5 Summary table of temperature projections for summer season (Temperature anomaly ◦C ranges) (Demircan et al. 2017)

Models	*Periods*	*RCP 4.5*	*RCP 8.5*
HadGEM2-ES	2016-2040	2-3	1.5-2
	2041-2070	2-3	3-4
	2071-2099	3-4	5-7
MPI-ESM-MIR	2016-2040	1-2	1.5-2
	2041-2070	1-2	2-4
	2071-2099	1.5-3	4-6
GFDL-ESM2M	2016-2040	0.5-1.5	1-2
	2041-2070	1.5-2	2-3
	2071-2099	1.5-3	3-5

The correction factors for excessive sunshine were calculated using three scenarios as best case (+1.5˚C), average (+3˚C) and worst case (+5˚C) scenarios. These scenarios are applied to the ERA5 dataset of temperature (1979-2018) and the daily durations when the temperature is between 30-35˚C and above 35˚C are calculated. Correction factors were calculated as the ratio of hours with temperatures higher than 30˚C to the total sunbathing time during 1979-2018 as 0.458 for best-case (+1.5˚C), 0.651 for average increase (+3˚C) and 0.994 for the worst-case scenario (+5˚C) of temperature rise.

3.2.3.2. Precipitation Projections

When the rainfall projections of General Directorate of Meteorology (as cited in Akçakaya et al. 2015) are examined, it is seen that precipitation anomalies are reduced, especially in areas where the models do not match. In this case, it is said that the average of multi-model results, decreases the median value calculated from individual models. Therefore, multi-model rainfall projections should be evaluated in the context of uncertainty. Although the changes in maps are shown with smoother transitions, the changes observed and to be observed show more stringent transitions (Akçakaya et al. 2015).

According to the rainfall projections and scenarios examined by Akçakaya et al. (2015), Hüdaverdi et al. (2016) and Demircan, et al. (2017), it is foreseen that there will be increase of precipitation in winter and spring seasons in the Black Sea region, while there will be decrease in the Mediterranean Region. These decreases will be between 30-40% in spring and between 50-70% in summer for 2016-2040 years, 50% in spring and 60-70% in summer except for coastal Aegean region for 2041-2077 years. So, it is assumed that the precipitation will no longer have a corrective factor while assessing the carrying capacities of beaches. Therefore, correction factor for precipitation is excluded from future RCC calculations.

3.2.3.3. Sea Level Rise Projections

The sea level rise data required for the calculation of shoreline retreat is obtained in two different ways. Firstly, the relative sea level rise values are obtained from two climate change scenarios as RCP 4.5 (moderate-emission-mitigation policy, best-case scenario) and RCP 8.5 (worst-case scenario) until 2100 (Figure 3.16) (Vousdoukas et al. 2017).

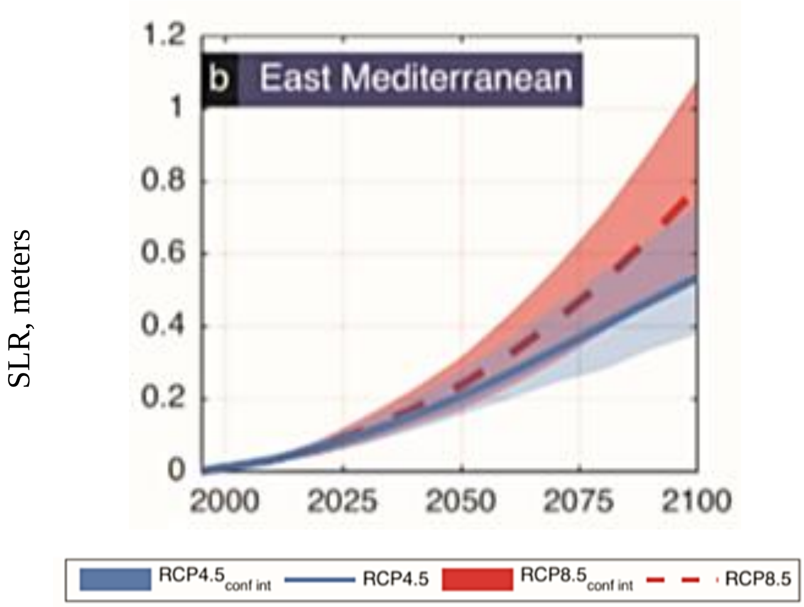

Figure 3.16 Time evolution of relative sea level rise (RSLR) for East Mediterranean under Representative Concentration Pathway RCP 4.5 and RCP 8.5. Lines express the ensemble mean and colored patches the inter-model range (defined by the best and worst-case scenarios (Vousdoukas et al., 2017).

Secondly, the mareograph data of sea level changes based on hourly sea level observations over a 20-year period along the Menteş coast were investigated in a study related to vulnurebility of coasts of Turkey to SLR by Alpar (2009). According to Alpar (2009), in east Mediterranean coast, tides are semidiurnal and mixed, and they are decreasing toward west Mediterranean. The temporal changes in tide gauges were computed as 6.2 mm/year for Menteş coast (nearest station to Kuşadası region) by linear trend estimation in this study (Alpar 2009). The sea level rise measurements presented in Figure 3.17 are mainly dominated by long-term sea level trends from relatively short data sets. However, these factors are the only available physical field data and they are in agreement with data of Karsiyaka tide gauge (Emery et al. 1988) as mentioned by Alpar (2009) indicating the vulnerability of low-lying margins in inner bay of Izmir to destructive storm surges.

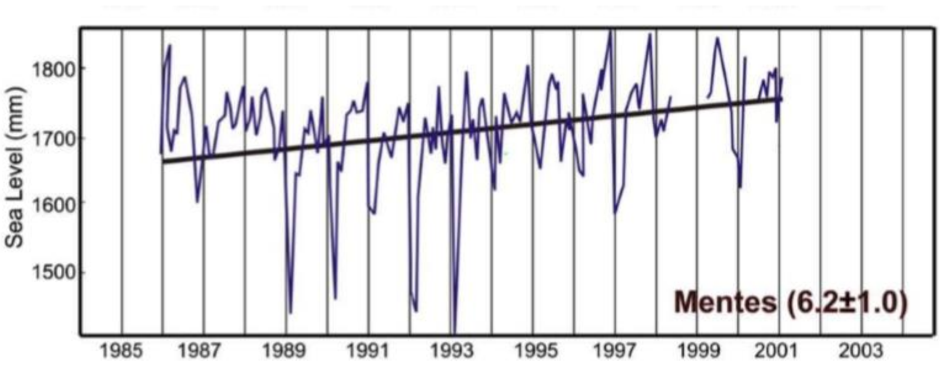

Figure 3.17 Sea-level trends of the mean monthly sea levels at Menteş (Alpar, 2009)

Using the temporal changes along the Menteş coast as 6.2 mm/year, the estimated SLR rise in the next 25 years is estimated as 0.155 m in average.

With these SLR data, the shoreline evolution under climate change is determined applying Bruun Rule to sandy beaches as Pamucak, Kadınlar, Davutlar and Güzelçamlı.

3.2.4. Field Observations

In order to analyze the physical characteristics of the beaches of study area and to have an idea about carrying capacities of them, field observations were conducted by me and two of my colleagues, Arian Khodkar and Mert Ülker on 6th and 8th of July 2019. Videos and pictures of people sitting/standing at the beach were taken with cameras of our phones while recording the GPS (Global Positioning System) data of the walking routes. This survey was conducted to compare the theoretical results with an example of more realistic values. The observations made once a day for Karasu, Kavaklıburun, Aydınlık and İçmeler for both days. Pamucak could only be visited once on July 8. Davutlar, Güzelçamlı and Kadınlar were observed twice on July 6, at noon (09:30-14:00) and in the evening (17:00-20:30). On 8th of July, these beaches were visited once.

The video recordings were used to count the number of people sitting on the beach twice by me. The number of beach users are presented in Table 3.6.

Table 3.6 number of beach users according to field observations, person

Beach	*Saturday*		*Monday*
	Noon	*Evening*	
Karasu	322		350
Kavaklıburun	350		220
Aydınlık	150		330
İçmeler	253		233
Güzelçamlı	1858	1432	1322
Davutlar	1247	908	2124
Kadınlar	793	340	1625
Pamucak	-		424

Three apparent weaknesses of field data collection in my opinion were;

Firstly, it was not possible to monitor the people at sea. Based on my prediction there were at least half times the number of people (counted at seaside) at sea. Secondly, the exact number of benches available in beaches of Dilek National Park were not counted. Most of these benches are located right behind the beach out of the study area; yet, at least half of the people here use the beach during the day even if they not continuously occupy a beach area. Thirdly, for the cases that the recording of the beach lasts for a shorter period of time, the number of people counted in the beach is constantly changing and it is quite impossible to find the estimated number of people on the beach in a short time. Karasu, Kavaklıburun, İçmeler, Aydınlık and Kadınlar beaches are much shorter in terms of beach length when compared to Pamucak, Davutlar and Güzelçamlı; so, video shooting of them lasted shorter (less than about

15 minutes). While, Pamucak, Güzelçamlı and Davutlar were shot by two person walking towards each other from opposite sides in more than one hour.

Some screenshots of the captured videos of beaches are given in Figure 3.18 showing Kadınlar beach on saturday (6th July 2019), Figure 3.19 as Kadınlar beach on Monday (8th July 2019), Figure 3.20 as three sections of Davutlar (D-1, D-2 and D-3), Figure 3.21 as Güzelçamlı, Figure 3.22 as two sections of Pamucak and lastly, Figure 3.23 showing the beaches of Dilek National Park.

According to the field observations, the Kadınlar beach is mostly crowded usually independent of the day and time of the day. In fact, more people were observed on Monday as a working day and the crowd were using the beach until the sun set completely around 9:00 o'clock at the evening.

Figure 3.18 Kadınlar beach. A: Saturday-morning (06 July 19-09:30) B: Saturday-evening (06 July 19-20:15)

Figure 3.19 Kadınlar beach at Monday-morning (08 July 19-10:40)

The northern parts of Davutlar were more crowded when compared to the southern part (Figure 3.20) towards Güzelçamlı beach (Figure 3.21). These areas are where the beach gets wider and there are mostly private summerhouses.

Figure 3.20 Davutlar beach as three sections of D-1, D-2 & D-3 at Saturday (06 July 19-11:50)

Figure 3.21 Güzelçamlı beach at Saturday (06 July 19-13:30)

The northern part of Pamucak beach which is more accessible to public entrance was more crowded (Figure 3.22). The southern parts were relatively far from the public facilities and sunbeds and umbrellas were only available for resort guests; so, they tend to stay at P-1 section of the beach. Considering the beach width on both sections, people were sitting on the beach at quite comfortable and far distances from each other.

Figure 3.22 Pamucak beach as two sections of P-1 & P-2 at Monday (08 July 19-15:30)

Beaches of Dilek National Park were also quite crowded (especially İçmeler and Aydınlık) and the crowd was diminishing towards the Karasu beach at the very end of the national park (Figure 3.23).

Figure 3.23 Dilek Peninsula National Park beaches. A: İçmeler, B: Aydınlık, C: Kavaklıburun & D: Karasu at Saturday (06 July 19, 12:30 - 15:30)

The Coordinates of the paths were recorded while shooting the videos; so, the number of people for specified areas were noted in order to determine the available space for each person. For D-3 section of Davutlar beach, the least space available for a person was 9-10 m^2 to the northern entrance of the beach (Figure 3.24). On the way to the southern parts of Davutlar beach and continuing towards Güzelçamlı, the space available increases to 25-30 m^2 for each user.

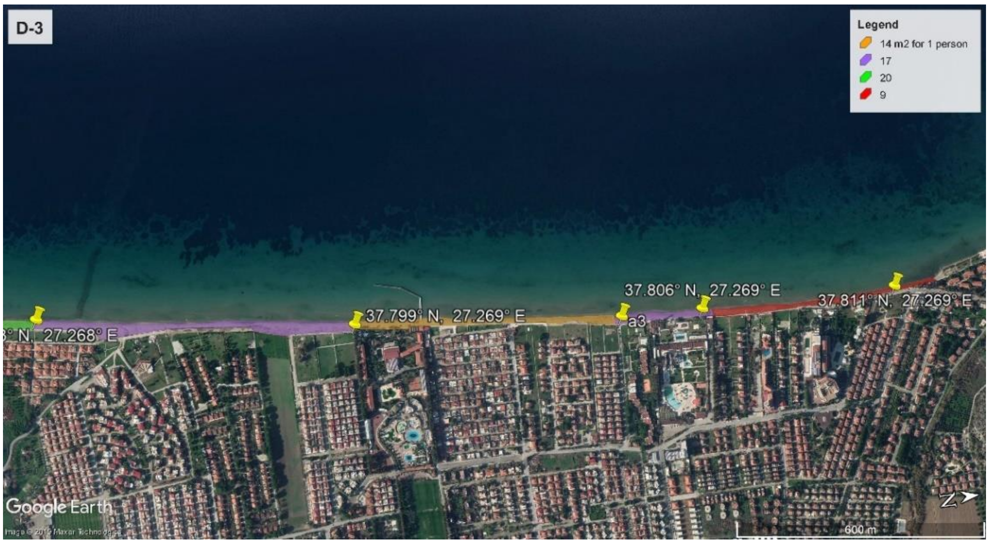

Figure 3.24 D-3 section of Davutlar, space available for each user as Z/a

For Kadınlar beach, both Saturday (6th of July 19) and Monday (8th of July 19) was very crowded and the largest average space available for each user was 11 m^2 and this number fell to the lowest areas available as 5 m^2 for each person to possibly sit on the beach. The spaces available for each user were also measured for beaches of National Park presented in Table 3.7.

Table 3.7 Space available for each person, m^2

	Saturday	*Monday*
Karasu	26	24
Kavaklıburun	19	30
Aydınlık	90	41
İçmeler	11	12

Among beaches of Dilek National Park, Aydınlık was observed to have a larger area for beach users individually when compared to the other beaches. Also, the available areas in the forest of this beach (just behind the beach) was relatively great and beach users could sit on the benches in a suitable distance from other beach users (Figure 3.25).

Figure 3.25 Aydınlık beach, screenshot of forest landscape at Saturday (06 July 19)

Yet, the situation was exactly the opposite for İçmeler. It was the most crowded beach in Dilek National Park and the main reason for it is that İçmeler is the nearest beach to the entrance of the park. In this beach nearly all of the zones were dense in population as shown in Figure 3.26. In this study, only the people sitting/walking on the beach were counted in order to find the number of beach users. Yet, as it can be observed from the photos, there were a high number of people in the sea or using the forest benches as the beach. Therefore, in order to measure the number of beach users in a more accurate way, it would be better to use aerial photography methods.

Figure 3.26 Screenshots of sea, beach and forest landscape of İçmeler

CHAPTER 4

METHODOLOGY

In this chapter, the methodology used for BCC assessment is presented and main dimensions of carrying capacity are discussed. The correction and limiting factors used in calculation of real carrying capacity are discussed and models to be used in shoreline evolution analysis of the study area are presented.

4.1. Beach Carrying Capacity Assessment

In this study, Cifuentes (1992) method, which was developed for carrying capacity analysis of natural protected areas, was discussed and applied for BCC calculation. The Cifuentes method (1992) is modified to calculate the physical and real carrying capacity of beaches. Main parameters used in the application of Cifuentes method (1992) for a beach consider the available beach area for recreational use, available space for each user, time of visits, physical properties of the region, the climatic and sea conditions that restrict the use of the beach and the erosion/accretion rates on the shore. These parameters are analyzed and the corrective factors limiting the use of the beach by using these parameters and limits are calculated. Thus, physical and real carrying capacities can be calculated by considering these parameters which are not the same for each beach and are closely related to the specific climatic conditions, geomorphological and physical characteristics of each beach. According to Cifuentes (1992), the following three main dimensions of carrying capacity is evaluated as mentioned below.

I. Physical Carrying Capacity (PCC)
II. Real Carrying Capacity (RCC)
III. Effective or Permissible Carrying Capacity (ECC)

Each level is a corrected capacity level of the previous level. Meanwhile, PCC is always larger than RCC, and RCC is greater than ECC (Cifuentes Arias et al. 1999);

$$PCC > RCC \geq ECC \tag{4.1}$$

The effective carrying capacity of a beach is the number of visitors that each beach area can bear after the existing management capacity is combined with the real carrying capacity of that area. It is calculated by the following formula according to Cifuentes (1992) (as cited in (Zacarias et al. 2011).

$$ECC = RCC \times Mc \tag{4.2}$$

Where, ECC is the effective carrying capacity, RCC is the real carrying capacity and Mc is the existing management capacity in terms of current status of quality and quantity of available infrastructure (bathrooms, public lighting, street/beach signaling, beach access, recreative areas, police/coastguard and fire stations, vehicles and means for assistance in natural disasters), facilities and services (restaurants, tent and bicycle rental and so on), staff capacity (lifeguards and coastguards), coastal management plans, information services and budget. These parameters can be assessed by evaluating the socio-cultural carrying capacity through perception study of beach users and field surveys (Andaman and Paul 2015; Huamantinco et al. 2016; Sridhar et al. 2016; Zacarias et al. 2011). However, there is lack of data related to socio-cultural carrying capacity and perception of beach users for Kuşadası area. Therefore, in this study, only physical and real carrying capacities were evaluated for specified urban and natural beaches of Kuşadası for which engineering solutions can be designed as part of management strategies.

4.1.1. Physical Carrying Capacity

Physical carrying capacity is defined as the maximum number of visits that is physically possible in a defined beach area within a given time period and is expressed by the following formula (Cifuentes Arias et al. 1999).

$$\mathrm{PCC} = A \times Z/a \times R_f \tag{4.3}$$

Here, A (m^2) is the total beach area suitable for public use, Z stands for number of visitors and a is the area available for each visitor (Z/a shows the ratio of the number of visitors for a defined area), and R_f is the rotation factor (Cifuentes Arias et al. 1999).

Google Earth satellite imagery is utilized for calculating the physical dimensions of the beaches as average length, width, and total available area (A) of each beach.

The maximum number of visitors that can use the beach at the same time can also be calculated using PCC formula by taking R_f as 1 (Equation 4.4). In essence, this value is simply the ratio of total beach area to available beach area for one visitor. This number can be used to determine crowding at any time for a beach for a selected comfort level of the visitors.

$$\text{PCC at same time} = A \text{ x } Z/a \tag{4.4}$$

Where, A is the available beach area (m^2) and Z/a is equal to 1 visitor/available space for each visitor (m^{-2}).

4.1.1.1. Space Required for Beach Users

The space available for each visitor (Z/a) is defined by considering the comfort of beach users. Yet, this parameter may vary based on the intensity of use in each beach. For instance, in urban beaches free for public usage, the area available for each user will be smaller when compared to the available area in beaches with restricted usage. This parameter is also defined by comfort level of the visitors. Cultural differences play an important role since in some cultures personal space concept is strict and demands a larger area. So, in addition to assumptions provided in the literature, field observations and user’s perceptions analysis through surveys and questionnaires (determination of the number of acceptable visitors) is recommended to determine this parameter.

According to BCC assessment in Monte Hermoso of Argentina, different conditions and criteria of the area occupied by the visitors were analyzed which considers three possible situations as high, medium and low occupancy with spaces of 5, 10 and 25 m^2 per person, respectively as it is shown in Figure 4.1 (Huamantinco et al. 2016). It is assumed that medium occupancy rate is usually preferred by beach users. So, 10 m^2 area is considered as the required space for each beach user in calculations of physical carrying capacity. Yet, this parameter may also vary according to the intensity of use in each beach.

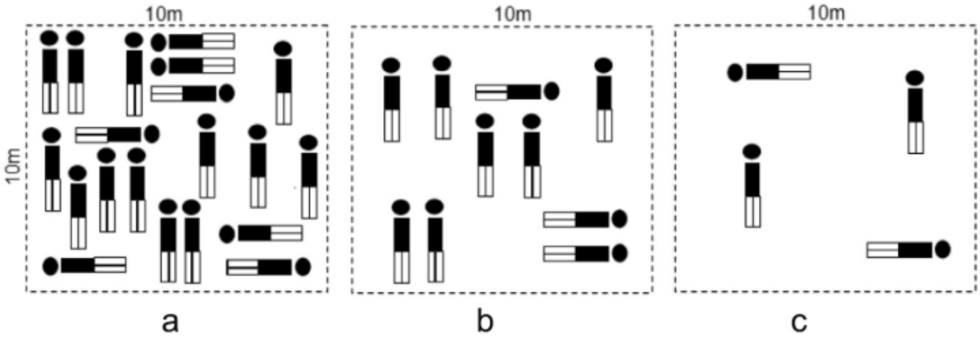

Figure 4.1 The conditions and criteria of the area occupied by the visitor (m2 per person): a) Z/a = 20 people/100 m^2, b) Z/a = 10 people/100 m^2 and c) Z/a = 4 people/100 m^2 (Huamantinco et al. 2016)

Moreover, according to another study on assessment of BCC in northern Portugal, 15 m^2 sand area is considered as comfortable space for beach users (Silva, Alves, and Rocha 2007). Lopez-Doriga et al. (2019) states three different values depending on the intensity of use for Catalan beaches. They define minimum area per user for high intensity beaches as 4 m^2, moderate intensity as 8 and low intensity as 12 m^2. Zacarias et al. (2011) defines optimum area available per user as 5 and 10 m^2 based on the total area of the beach for Portuguese beaches.

In Turkey, for recreational carrying capacity assessment of Erikli, Limanköy and Beğendik beaches in İğneada, available area of 22 m^2 to 55 m^2 per each person was determined according to the beach usage densities in this region (Küçükaltan and Yılmaz 2011).

The space required for each visitor to have a comfortable stay at the beach may vary according to the type of the beach. For instance, for urban beaches with intensive use such as Kadınlar, limited and narrower areas may be available for each user. So, practically this value varies depending on the available space for each user considering the comfort of beach users wherever it is possible. For the beaches of Kuşadası, the areas of 10 and 15 m^2 were used in calculations of physical carrying capacity in order to discuss the effect of perception of personal space on the results.

4.1.1.2. Rotation Factor

Rotation factor (R_f) is determined using the ratio of the time the beach is open to use to the average time of each visit to the beach. This parameter depends on the availability of infrastructure of the beaches, the sunrise and sunset hours, the restrictions on the entrance/ exit of the beach and the purpose of visits. The rotation factors are calculated as the possible numbers of visits for each user per day, which depends on how much time a visit, take place. Shorter visits mean more visitors can use the same area in a day which means the number of visits will be higher for the beach. This parameter may also vary based on the management type of the beach. For instance, people are likely to spend longer times at the beaches in Dilek Peninsula National Park since there are entrance fees. This means there will be minimum rotation among the visitors in a day.

Considering these factors and based on the field observations, the time the public urban/ non-urban beaches are available to use is assumed as 06:00-20:00. The peak range is between 09:00 in the morning and 18:00 in the evening for four natural beaches of Dilek National Park (Karasu, Kavaklıburun, Aydınlık & İçmeler) and three urban beaches of Davutlar and Güzelçamlı. For Pamucak, this range may vary according to the crowding density of the hotels across the Pamucak beach. According to the field observations made at the first week of July of this year, the peak range were between 11:00 in the morning and 18:00 in the evening. So, the time that public beaches of Kadınlar, Pamucak, Davutlar and Güzelçamlı are open to use is considered as 9 hours per day.

As there is no data on duration of visits for the beaches of Kuşadası, it was assumed that the visits to public urban beaches lasted approximately 4 hours based on a study for Spanish beaches (Solé 2007). As the beaches considered in Solé (2007) are part of the Mediterranean tourism chain, this approach is believed to represent the conditions for Kuşadası beaches as well. So, for Kadınlar, Davutlar and Güzelçamlı beaches the rotation factor is calculated as 2.25. Yet, for Pamucak beach which is a natural beach relatively far from the city, the number of visits per day is accepted as 1 time per day. For the natural beaches of Dilek Peninsula-Büyük Menderes National Park these values are also different than public beaches. Karasu, Kavaklıburun, Aydınlık and İçmeler beaches are open to use between 08:00-17:00 according to T.C. Ministry of Agriculture and Forestry General Directorate of Nature Conservation and National Parks. Since, there is an entrance fee for the beaches, the number of visits per day is considered as one.

4.1.2. Real Carrying Capacity

Real carrying capacity is defined as the maximum allowed number of visits to a defined area after application of certain corrective factors to physical carrying capacity (Cifuentes Arias et al. 1999). The intensity of beach use is not homogenous within a day or in a season. Beach tourism is highly dependent on environmental and climate conditions. The aim here is to ensure that these climatic, physical and ecological conditions that restrict the use of the evaluated area throughout the year are included in the method and to express the number of visitors in a more realistic way. Therefore, these conditions as corrective parameters is essential to measure the sustainability level of a beach. RCC can be expressed with the following formula (Cifuentes Arias et al. 1999) as;

$$\mathrm{RCC} = \mathrm{PCC} \times \mathrm{Cf}_1 \times \mathrm{Cf}_2 \times \ldots\ldots \times \mathrm{Cf}_n \tag{4.5}$$

Where, Cf_i is the correction factor, expressed as a percentage. Therefore, the formula measuring RCC is applied as the following equation (Cifuentes Arias et al. 1999).

$$\mathrm{RCC} = \mathrm{PCC} \times \frac{(100\text{-}\mathrm{Cf}_1)}{100} \times \frac{(100\text{-}\mathrm{Cf}_2)}{100} \times\ldots\times \frac{(100\text{-}\mathrm{Cf}_n)}{100} \tag{4.6}$$

Corrective factors are calculated for each beach to reflect their different characteristics. These factors are expressed in percentages and they are calculated with the following general formula (Cifuentes Arias et al. 1999).

$$\mathrm{Cf} = \left(\frac{\mathrm{M}_l}{\mathrm{M}_T}\right) \times 100 \tag{4.7}$$

Where, M_l is the limiting value of the variable and M_T is the total magnitude of that variable.

4.1.2.1. Correction Factors Used in the Study

The corrective factors are defined by the region-specific physical features and climatic conditions of each beach which affect the satisfaction level of users and limits the beach use. For instance, the excessive sunshine, rainy or snowy weather conditions, stormy days, shoreline retreat, accessibility to beach (degree of difficulty and slope of trail), temporary closure of the site due to maintenance or management reasons, disturbance to wild life (Sayan et al. 2011), wave interactions, vegetation cover and so many other factors may disrupt or limit beach use and visitor density.

For this study, climatic conditions are defined as one group of correction factors that limit the beach use due to visitor preference. The underlying climate factors that may limit the beach usage are selected as air temperature (excessive sunshine), precipitation type and intensity, wind speed, and total cloud cover. At first, the comfort levels of these factors are defined; so that, the period satisfying these acceptable levels can be used in analysis of carrying capacity. In this study, as all the beaches are located close to each other, the climate conditions of Kuşadası is used to calculate these correction factors for all the beaches. In other words, these correction factors are constant for every beach.

Another correction factor is defined to determine shoreline evolution. This correction factor represents the physical limitation of beach area due to geomorphological processes and do not depend on the visitor profile.

Temperature/ Excessive Sunshine

It is known that the temperature comfortable for the visitors to stay at the beach is between 18-25°C (Göktüğ 2011). However, the air temperature usually rises above 25°C during summer which makes the beach users uncomfortable so much that they do not prefer to spend time outdoors. In other words, at this period when there is an excessive sunshine, the usage of beach is restricted based on visitor preference. So, this period should be excluded from the total time when beach is used in order to find the real carrying capacity of the beach. The 2m hourly temperature dataset for 1979-2018 years were collected from ERA5 and organized using MATLAB to obtain the average, average minimum and maximum temperatures per months for 40 years as it is presented in Table 4.1. In addition, the average sunbathing hours for each month during years of 1941-2018 were collected from Aydın Meteorological Station dataset (General Directorate of Meteorology 2018).

Table 4.1 Average values of temperature in Kuşadası and average sunbathing durations in Aydin

Months	*Average Temperature, ˚C*	*Average Highest Temperature, ˚C*	*Average Lowest Temperature, ˚C*	*Average Sunbathing Time, hours/day*
January	9.8	14.7	4.3	4.1
February	10.3	15.2	4.7	4.6
March	12.3	16.5	7.1	5.9
April	15.6	19.5	11.7	7.2
May	19.9	23.7	15.9	8.5
June	24.4	28.2	20.6	10.1
July	27.1	29.9	24.0	10.8
August	27.2	30.0	24.3	10.3
September	23.8	27.0	20.4	9
October	19.4	23.1	14.5	6.9
November	14.7	19.1	9.2	5
December	11.2	16.1	5.3	4.1

In order to calculate the correction factor for excessive sunshine, first, the total number of hours of sunshine (total sunbathing time) for the assessment period is calculated as;

$$M_{\text{temperature}} = (\ 8.5 + 10.1 + 10.8 + 10.3 + 9 + 6.9\ ) \times 30 \tag{4.8}$$

$$M_{\text{temperature}} = 1668\ \frac{\text{hours}}{\text{May-October}}$$

Average temperatures are between 19-27˚C in May-October months, the highest temperature reached in these months is 30˚C. The disturbing temperatures for staying at the beach is assumed as 30-35˚C and above. The average timetable of specified temperatures per month for 40 years is given in Appendix A. In Table 4.2, the number of hours when the sunshine is intense (temperature is between 30-35˚C and above 35˚C) for each month for 40 years is presented.

Table 4.2 Average number of hours in a month at specific temperatures for Kuşadası

Hours/month	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
30-35°C	0	0	0	0	2.65	67.33	177.33	176.35	41.08	1.38	0	0
>35°C	0	0	0	0	0	1.98	12.5	13.4	0.1	0	0	0

The excessive sunshine correction factor for the specified months of May-October can be calculated as;

$$C_{f,\,temp} = \frac{\text{30-35°C and above hours}}{\text{Total sunbathing time}} \tag{4.9}$$

$$C_{f,\,temp} = \frac{(2.65+67.33+177.33+176.33+41.08+1.38)+(1.98+12.5+13.4+0.1)}{1668 \text{ hours}} = 0.29$$

Therefore, corrective factor for excessive sunshine is determined as 0.29 or 29% of time during Months of May to October.

Precipitation

Precipitation is another climate factor that makes the beach users uncomfortable and limits beach usage; so, it is identified as correction factor. The total precipitation dataset for 1979-2018 years was collected from ERA5 and organized using MATLAB to obtain the average number of days with rainfall, intensity and duration of rainfall per months for 40 years. This data is given in Appendix. Based on this dataset, the average number of days with rainfall is 172 days/year and the average duration of rainfall is 2151 hours/year for Kuşadası. 32% of rainfall is in autumn, 36% in winter, 23.8% in spring and 8.7% of it falls in summer.

According to the National Meteorological Library and Archive reports (Jebson 2007), precipitation up to 1 mm/hour is scaled as moderate drizzle and precipitation higher than 2 mm/hour is scaled as moderate shower. Once rain starts, visitors prefer to leave the beach therefore rainfall is a limiting factor. The average number of hours in a month for rainfall is calculated for both drizzle and shower conditions (Table 4.3).

Table 4.3 Average number of hours in a month with specified rainfall intensities

Hours in a Month	*Precipitation > 1 mm/hour*	*Precipitation > 2 mm/hour*
January	46.13	17.40
February	34.35	11.78
March	27.90	10.53
April	13.98	4.95
May	7.15	2.25
June	1.43	0.23
July	0.15	0.00
August	0.18	0.05
September	5.45	3.15
October	17.13	9.18
November	37.78	17.55
December	49.20	20.35
Total	240.8	97.4

Correction Factor for rainy hours during May-October months with intensity higher than 0.001 m/hour is calculated as;

$$C_{f,\ \text{rain-1}} = \frac{\text{0.001 m/hr and above duration in hours}}{\text{6 months x 30 days x 24 hours}} \tag{4.10}$$

$$C_{f,\ \text{rain-1}} = \frac{(7.15+1.43+0.15+0.18+5.45+17.13)}{6 \text{ x } 30 \text{ x } 24} = 0.0073$$

Correction Factor for rainy hours during May-October months with intensity higher than 0.002 m/hour is calculated as;

$$C_{f,\ \text{rain-2}} = \frac{\text{0.002 m/hr and above duration in hours}}{\text{6 months x 30 days x 24 hours}} \tag{4.11}$$

$$C_{f,\ \text{rain-2}} = \frac{(2.25+0.23+0.05+3.15+9.18)}{6 \text{ x } 30 \text{ x } 24} = 0.0034$$

Therefore, the correction factors for rainfall are determined as 0.0073 and 0.0034 for two different rain intensity. Since climate of Kuşadası is very dry during summer months, rainfall parameter is not going to be a significant limiting factor.

In addition to rainfall, snowfall should also be considered; yet, due to the climate of Kuşadası, snowfall is not considered as a correction factor for beach use. According to the ERA5 datasets, months with slight snowfall are generally January, February, March and December.

Total Cloud Cover

According to the National Meteorological Library and Archive reports (Met Office 2013), 6/8th sky cover which is called “broken sky” may be uncomfortable for beach users; since, they could worry about the rainfall and leave the beach. It also inhibits the sunshine when 6/8th of the sky is covered. Taking this level of cloud cover into account; it is assumed that the sky is cloudy when the cloud cover is 80%. So, days with cloudiness higher than 0.8 are obtained from ERA5 datasets to calculate the cloudiness correction factor. Since, precipitation is directly connected with cloudiness, the days with precipitation are excluded from the days with 80% cloud cover. The average duration (hours in a month) with cloudiness higher than 80% and without rainfall is presented in Table 4.4.

Table 4.4 Monthly average values of total cloud cover in Kuşadası (1979-2018)

Hours in a Month	*Duration with cloudiness higher than 80% (during 06:00-20:00)*	*Duration with cloudiness higher than 0.8 without including the rainy days (during 06:00-20:00)*
January	164.85	44.45
February	147.63	46.08
March	143.68	64.50
April	115.55	71.20
May	79.48	54.33
June	20.40	14.58
July	1.73	1.45
August	1.50	0.98
September	18.05	10.98
October	82.13	42.83
November	135.35	50.50
December	175.43	44.28
Total	1085.75	446.125

Correction Factor for cloudy hours during May-October months with cloud cover higher than 80% is calculated as;

$$C_{f,\ \text{cloudiness}} = \frac{\text{Duration of hours with cloudiness higher than 80\% (extracting the rainy days)}}{\text{6 months x 30 days x 14 hours}}$$

$$C_{f,\ \text{cloudiness}} = \frac{(54.33+14.58+1.45+0.98+10.98+42.83)}{\text{6 months x 30 days x 14 hours}} = 0.05 \qquad (4.12)$$

The correction factor for cloudiness is determined as 0.05 or 5%.

Wind Speed

Another factor that restricts beach usage is the windy weather; since, the sands on the beach take off with the wind and the sea starts to fluctuate which will disturb the users. According to Beaufort Wind Scale System, the weather conditions where the wind speed is approximately 5.5-8 m/s are defined as moderate windy which raises dust and loose paper. This wind speed also causes the small waves to expand and the foam of the broken waves to become more frequent. So, conditions where wind speed is 8 m/s or less (<28.8 km/h) are defined as comfortable weather for beach visitors. According to ERA5 datasets of Kuşadası for the last 40 years (Figure 4.2 and Table 4.5), the average duration with wind speed higher than 8 m/s is 56 hours per year.

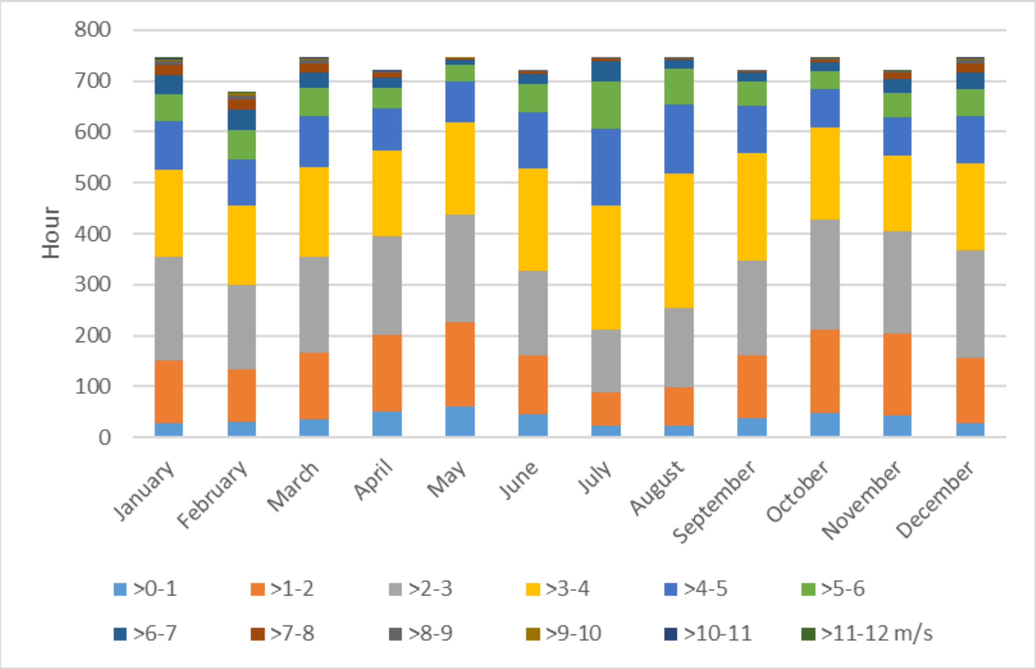

Figure 4.2 Graph of wind durations (hours/year) for the last 40 years (1979-2018)

Table 4.5 Monthly average values of wind speed in Kuşadası (1979-2018)

Months	*Average number of days with wind speed higher than 8 m/s*	*Duration with wind speed higher than 8 m/s, (hours)*
January	3.08	11.73
February	3.58	14.30
March	2.55	9.95
April	1.25	3.48
May	0.23	0.73
June	0.20	0.58
July	0.08	0.18
August	0.05	0.15
September	0.13	0.43
October	0.40	0.85
November	1.48	4.33
December	2.43	8.85
Total	15.43	55.53

Correction Factor for stormy days during May-October months with speed higher than 8 m/s is calculated as;

$$C_{f,\text{ wind}} = \frac{\text{Duration with wind speed higher than 8m/s in hours}}{\text{6 months x 30 days x 24 hours}} \tag{4.13}$$

$$C_{f,\text{ wind}} = \frac{(0.73+0.58+0.18+0.15+0.43+0.85)}{6 \text{ x } 30 \text{ x } 24} = 0.0007$$

The correction factor for wind is determined as 0.0007 which means that although windy weather can limit the use of beach, the significance for Kuşadası is very low.

Shoreline Evolution

The coastline is one of the most dynamic environments in the world because of being the interface between land and sea where many interactions are taking place causing erosion or deposition in the coastal region over time. These interactions changing the coastal shorelines can be grouped as geological, morphological, hydrodynamic, climatological, biological and anthropogenic factors (as a result of population growth and developing urbanization) (Castelle et al. 2018; Escudero-Castillo et al. 2018; Labuz 2015; Mahabot et al. 2017; Oyedotun 2014; Pagán et al. 2017). Waves, tides, storms and other physical processes cause erosion or deposition that lead to a change in the usable area on the beaches over time. While erosion is a limiting factor on the number of visitors, deposition will have a positive impact by increasing the resiliency of the beach to future threats such as sea level rise. Therefore, it is important to integrate shoreline evolution as a corrective factor in the assessment.

There are many methods to determine and model the shoreline evolution. While some of them require high level of data and computing requirement, some rely on GIS application and conceptual approaches. The selection of the model depends on the level of detail required by the study as well as the available dataset. In this study, two time scales are considered to analyze the shoreline evolution. First, the present trend in the shoreline change is assessed to determine the possible impact on the beach carrying capacity at present and in the very near future (<10 years). Secondly, the possible shoreline evolution under sea level rise is determined to integrate impact of climate change on the beach carrying capacity until 2100. For the first time Digital Shoreline Analysis System (DSAS) software (U.S. Geological Survey 2018) is used by utilizing available Google Earth images. For the climate change conditions, Bruun Rule (Bruun 1954) is applied to sandy beaches. The next section provides information on these methods.

Digital Shorline Analysis System (DSAS)

The DSAS software originally was developed in the early 1990's and it has been a central component of the U.S. Geological Survey's Coastal Change Hazards project in order to provide not only shoreline change rate information and related statistical data but also to assess the positional changes of glacier limits, land-cover, river edge boundaries and such processes over time. National and state governments around the world have been using this tool to support resource management and critical coastal decision-making; since, DSAS can be used for large amounts of data collected on a national scale and it is able to obtain the necessary statistical data to establish the reliability of calculated results (U.S. Geological Survey 2018). Two noteworthy recent studies about using DSAS technique for long-term process of the shoreline change detection, coastal zone monitoring and analyze the consequences of shoreline evolution are cases of North Sinai coast, Egypt by Nassar et al. (2019) and case of coastal beaches-Andalusia, Spain by Prieto-Campos et al. (2018). Also, DSAS have been used in many studies in order to record the short-term and long-term historical natural and anthropogenic coastal dynamics (Carrasco et al. 2012; Montreuil and Bullard 2012; Restrepo 2012; González Villanueva et al. 2013; Jabaloy-Sánchez et al. 2014), to assess the change rates of shoreline evolution (erosion/accretion) in response to sediment transport/supply (Brooks and Spencer 2010; Houser and Mathew 2011) or extreme events (Houser, Hapke, and Hamilton 2008), to model shoreline/cliff profile developments (Hackney et al. 2013; Thébaudeau et al. 2013) and cliff retreat and erosion (Rio and Gracia 2009; Brooks et al. 2012; Katz and Mushkin 2013; Young et al. 2014) as cited by Oyedotun (2014).

DSAS software application which works within the Environmental System Research Institute's (ESRI) Geographic Information System (ArcGIS) software is used to compute the rate of change statistics for the time series of shoreline data which can be obtained from variety of sources as digital orthophotos, georeferenced historical coastal-survey maps or satellite imagery, collected by global-positioning-system field surveys, or extracted from LiDAR (Light Detection and Ranging) surveys (Himmelstoss et al. 2018).

In DSAS, a reference baseline adjacent to the series of shorelines of each beach is assigned onshore or offshore relative to the series of shoreline positions. Afterwards, a series of transects intersect the baseline perpendicularly (orthogonally) from each shoreline in a defined spacing and with specified length; so that, the change rates can be calculated (Himmelstoss et al. 2018). The steps of a typical DSAS workflow is given in Figure 4.3.

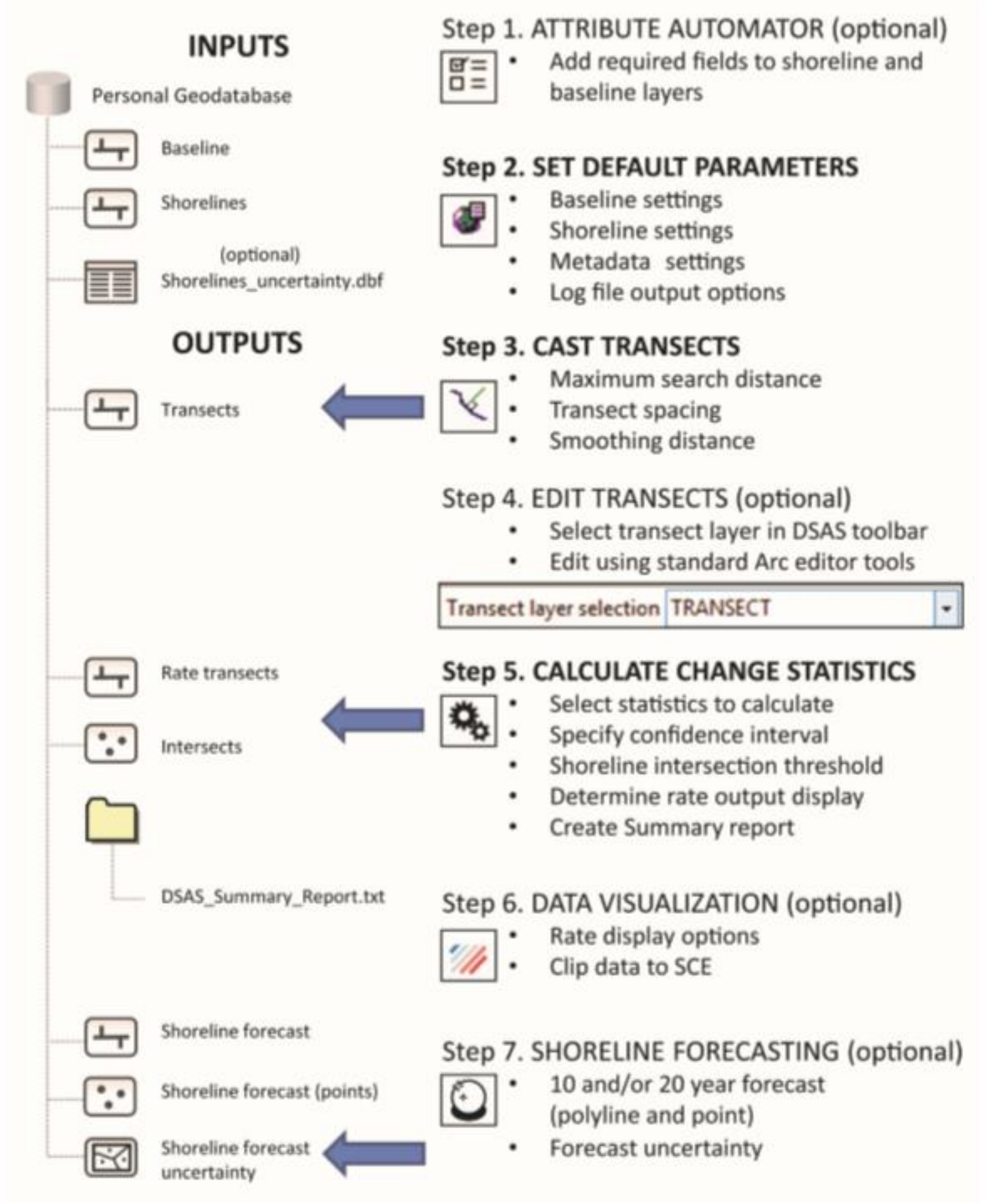

Figure 4.3 The Digital Shoreline Analysis System (DSAS) workflow with steps necessary to establish transects and compute change-rate statistics. SCE, shoreline change envelope (Himmelstoss et al. 2018).

The following rate-change statistics are calculated as outputs of DSAS.

Shoreline Change Envelope (SCE): SCE represents the greatest distance between all the shorelines of each beach in meters. In other words, this value represents the greatest distance on which the shoreline has been retreated or gained over time (Himmelstoss et al. 2018) .

Net Shoreline Movement (NSM): NSM represents the distance between the oldest and the youngest shorelines of each beach in meters (Himmelstoss et al. 2018). Negative value for net shoreline movement shows that there is a retreat in shoreline positions (erosion) and positive values stands for accretion in the beaches.

End Point Rate (EPR): EPR represents the rate of change between the oldest and the youngest shorelines of each beach by dividing NSM by the time between the oldest and youngest shoreline (Himmelstoss et al., 2018). The uncertainty of EPR (EPR_{unc}) is calculated using the Equation 3.7;

$$EPR_{unc} = \frac{\sqrt{(\text{uncy A})^2 + (\text{uncy B})^2}}{\text{date A-date B}} \tag{4.14}$$

Where, uncy A defines uncertainty of shoreline A, uncy B defines uncertainty of shoreline B, date A is the date of most recent shoreline and date B is the date of the oldest one (Himmelstoss et al. 2018).

Linear Regression Rate (LRR): Linear Regression Rate (LRR) represents the rate of change of shorelines which is obtained by plotting the distance of shorelines from baseline with respect to time (years) and calculating the slope of the plot as LRR without considering the factors causing any possible outliers or any other rate change relative to other statistics. Calculation of this change rate is based on fitting a least-square regression line to all shoreline points for a transect to present the percent of transects which are either erosional or accretional (Himmelstoss et al. 2018).

Weighted Regression Rate (WLR): The difference between LRR and weighted linear regression rate (WLR) is that for WLR a best-fitted line is given considering the effect of uncertainty of shoreline positions by giving more weight on shorelines with smaller positional uncertainties (Genz et al. 2007) (as cited in Himmelstoss et al. 2018).

$$w = 1/e^2 \tag{4.15}$$

Where, w is a function of the variance in the uncertainty of the shoreline uncertainty value, e. This value should be calculated considering the following uncertainties (Warnasuriya, Gunaalan, and Gunasekara 2018);

- Uncertainty due to the positional shift of satellite image (in meters): This uncertainty can be minimized by georeferencing the shoreline data and subject them to a same projection in ArcGIS.
- Uncertainty due to the digitizing error (in meters): Since the resolution of all satellite imagery are not all reliable, there may be mistakes while digitizing the waterline. So, the same shoreline for each beach can be digitized manually multiple times in order to obtain the uncertainty due to deviations of digitizing.
- Uncertainty due to the tidal error (in meters): Meteorological conditions and any combination of astronomical conditions affecting the tidal oscillations, seasonal fluctuations and short time oscillations are important in defining the water level of when the satellite image is obtained and define the uncertainty due to these fluctuations.

According to Dolan et al. (1991), the accuracy and precision of evaluated shoreline change rates depends on resolution of the images/maps which directly affects the accuracy of the shoreline positions as well as other factors such as; temporal resolution, uncertainty of shoreline positions, the proximity of each observation to the time of an actual change in the trend of shoreline movement, the period of time between the shoreline measurements and the total time span of shoreline data.

Therefore, understanding the scope and purpose of the study and considering the sensitivity and accuracy necessary for calculation of statistics and the availability of satellite imagery in provincial, national or global scale used in shoreline evaluation by DSAS is essential to obtain the most reliable results.

For the scope of this study and time scale, it is necessary to provide 1-Dimensional information on the waterline at the coast on different times; so that, the landward retreat or accretion of the shoreline and change rate of beach width can be assessed over time. For this purpose, medium spatial resolution satellite images are used from historical datasets of Google Earth platform (ranging from ~30 m to 0.31 m resolution) which also involves all multispectral data from the earth's surface provided by National Aeronautics and Space Administration (NASA) and European Satellite Agency (ESA) free of charge. According to Gerben et al. (2017) the validity and accuracy of waterline positions obtained from Google Earth satellite imagery have been studied by multiple researchers whom found the waterline position obtained from satellite imagery close to in-situ data (Pardo-Pascual et al. 2012, Garcia-Rubio et al. 2015). Since there are coasts with alternative combinations of shoreline types as high, low and mean water level shorelines, the proxy-datum bias should be used in calculation of rates to report only the rates where bias has been applied in order to obtain accurate results. For this purpose, meteorological conditions and any combination of astronomical conditions affecting the tidal oscillations, seasonal fluctuations and short time oscillations of when the satellite imagery is obtained is important to define the type of shoreline.

To run the DSAS tool, some steps were followed manually as it is briefly explained;

- First of all, all of the shoreline vectors were manually digitized for the specified years and added as layers in ArcMap. The shorelines were subjected to TUREF/TM27 projection. Also, the shorelines of each beach were manually automated by editing and moving each shoreline to a specified unchanged point which applies for all (for instance a corner of a building which is unmoved since then) to minimize the uncertainty due to positional shifts of satellite imagery of Google Earth.

- All shorelines were merged into a same feature in a same projected coordinate system (TUREF/TM27). The dates of each shoreline data were assigned and properly attributed in in shoreline feature-class attribute table for further statistic calculations by DSAS.

- The uncertainties due to digitizing of the shorelines were also assigned for each shoreline of each date. This uncertainty level was measured by manually digitizing the same shoreline of each date 3 times to include the digitizing errors in calculation of weighted linear regression rates.

- Reference baseline adjacent to the series of shorelines were assigned for each beach individually, onshore or offshore relative to the series of shoreline positions (Figure 4.4).

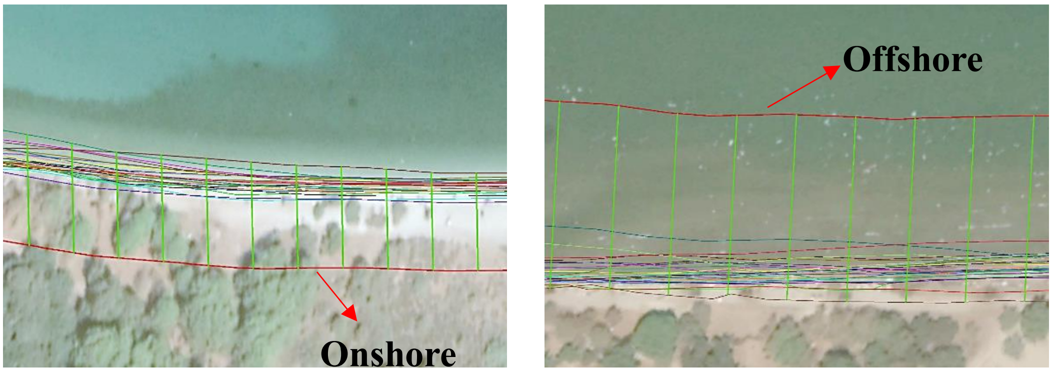

Figure 4.4 Example for onshore (left) and offshore (right) baselines

- Afterwards, a series of transects intersecting the baseline perpendicularly (orthogonally) from each shoreline were casted automatically by DSAS tool with 20 meters spacing (specified manually); so that, the change rates can be calculated. The transects are selected (search distance as selected by user) to be drawn to a length that covers all of the shoreline data.

- Since the orientation of the baseline is drawn adjacent to the position of merged shorelines, the casted perpendicular transects may intersect the shorelines in different angles which will change the change rate statistics results. Hence, the baseline is selected to be smoothly changing along the coast with respect to the position of shorelines.

- In order to calculate change rate statistics, the layer of interest (beach) is selected in DSAS toolbar extension and after specifying the confidence interval (as 90% for all calculations), the change rate statistics of SCE, NSM, EPR, LRR and WLR are calculated and presented in a summary report. Also, the rates of SCE, EPR and WLR were selected to be displayed using different color maps for each beach.

Results of SCE is presented here to show the extent that the shoreline changed in the last 15 years. This statistic provides information on the most dynamic beaches in the region. WLR is presented as the result of this statistic is used to determine the correction factor of shoreline evolution in RCC calculations. The results of NSM, EPR and LRR and illustrations for all the change rates are given in Appendix B.

Shoreline Change Envelope (SCE)

Among the natural beaches of Dilek National Park, İçmeler has the greatest SCE, among the urban beaches, Davutlar has the greatest SCE and among all of them, Pamucak has the greatest shoreline change since 2004. The significant difference between average, average maximum and average minimum SCE distances between shorelines of Pamucak is possibly because of the sediment deposition of the Küçük Menderes stream on the northern side of Pamucak beach while the southern parts have lower SCE. Also, Davutlar seems to have differences in shoreline change distances along the beach because of differences in beach widths along this coast. While northern parts of Davutlar has narrower beach widths, the southern parts near the Güzelçamlı are wider. So, this could be the reason for differences in average, maximum and minimum shoreline change distances. The shoreline distance values are nearly the same all along the İçmeler beach (Table 4.6). The SCE illustrations of beaches of the study area are given in Appendix B.

Table 4.6 Shoreline Change Envelope values for beaches

Beach	*Maximum Distance (SCE), m*	*Average Distance, m*	*Minimum Distance, m*
Karasu	15.71	7.94	1.57
Kavaklıburun	10.88	6.59	3.58
Aydınlık	17.98	11.05	8.1
İçmeler	25.63	23.86	21.69
Güzelçamlı	26.48	12.1	6.57
Davutlar	51.4	14.26	4.74
Kadınlar	20.3	11.13	5.74
Pamucak	87.07	38.4	19.9

Weighted Linear Regression Rate (WLR)

According to the WLR approach, Güzelçamlı has the greatest erosion rate with nearly 85% of all transects being erosional and Pamucak has the greatest accretion rate with 87% of all transects being accretional among all of the beaches of study area (Table 4.7). The possible uncertainties due to shifts in positions of shorelines are attempted to be resolved as described;

- Uncertainty due to the positional shift of satellite image (in meters): The shorelines were subjected to TUREF/TM 27 projection and manually automated; so that, the uncertainty due to positional shifting of images are minimized.

- Uncertainty due to the digitizing error (in meters): Since the resolution of all satellite imagery are not all reliable, there may be mistakes while digitizing the waterline. So, the same shoreline for each beach was digitized three times in Google Earth in different times in order to obtain the uncertainty due to deviations while digitizing.
- Uncertainty due to the tidal error in meters: Since there are coasts with alternative combinations of shoreline types as high, low and mean water level shorelines, the proxy-datum bias should be used in calculation of rates to report only the rates where bias has been applied in order to obtain accurate results. For this purpose, meteorological conditions and any combination of astronomical conditions affecting the tidal oscillations, seasonal fluctuations and short time oscillations of when the satellite imagery is obtained is important to define the type of shoreline. According to a recent study about examination of barotropic tidal circulations in the Mediterranean, the Marmara, the Black and the Azov seas (MMBA system using a 3-Dimensional finite element hydrodynamic model (SHYFEM), semi-diurnal tidal (M_2) wave has significant amplitude of approximately 10 cm at the eastern side of Mediterranean Sea, diurnal tidal (K_1) wave has amplitude of few centimeters over most of the Mediterranean Sea, long-term tides (M_f) have amplitudes lower than 0.4 cm and residual currents are mostly lower than 1 cm/s in eastern side of Mediterranean Sea (Ferrarin et al. 2018). Therefore, in this study, the effects of these processes on sea level were assumed as negligible; so, the shoreline evolution rates are calculated assuming mean sea level all along the coast in satellite imagery provided from Google Earth. This uncertainty value is assumed as negligible; since tidal wave amplitudes and tidal currents are significantly low in eastern Mediterranean Sea (Ferrarin et al., 2018).

Table 4.7 Weighted Regression Rate values for beaches

Beach	*Average rate with reduced uncertainty*	*Percent of all transects that are erosional*	*Percent of all transects that are accretional*
Karasu	-0.03 +/- 0.22	45.83	54.17
Kavaklıburun	-0.02 +/- 0.25	51.92	48.08
Aydınlık	-0.23 +/- 0.14	82.5	17.5
İçmeler	0.43 +/- 0.21	0	100
Güzelçamlı	-0.26 +/- 0.11	84.97	15.03
Davutlar	0.31 +/- 0.17	26.86	73.14
Kadınlar	0.07 +/- 0.23	24.24	75.76
Pamucak	1.54 +/- 0.2	12.67	87.33

Taking the effects of outliers, WLR change rates were used to calculate the erosion/ accretion correction factors by applying WLR to the current width of each beach. An example for calculation of the correction factor for Karasu with beach width of 18 meters and average WLR value of (-0.03) is as follows;

$$\left(\frac{18 - 0.03}{18}\right) \times 100 = 99.83\%$$

$$Cf_{erosion} \text{ (for Karasu)} = 1 - 0.9983 = 0.0017$$

According to the results given in Table 4.8, the change rates of beach widths are nearly negligible, and they are assumed as 1 while calculating RCC except for Pamucak and İçmeler for which the average weighted regression rates are notably accretional.

Table 4.8 Erosion correction factors using Weighted Regression Rates

Beach	*Erosion/Accretion Correction Factor, $(1-Cf_{erosion})$*	*Assumed value for calculation of RCC*
Karasu	0.998	1
Kavaklıburun	0.997	1
Aydınlık	0.987	1
İçmeler	1.043	1.043
Güzelçamlı	0.995	1
Davutlar	1.009	1
Kadınlar	1.004	1
Pamucak	1.024	1.024

4.1.2.2. Future Shoreline Change (Bruun Rule)

Secondly, the future evolution of beaches is assessed to determine the effect of sea level rise on the carrying capacity. One of the most important reasons for coastal recession is known as sea level rise mainly caused by global climate change due to the enhanced greenhouse effect (IPCC, 2001, 2007). As an example, impact of sea level rise on the beach management is presented in Figure 4.5 according to a case study for Catalan beaches (Jiménez et al. 2017).

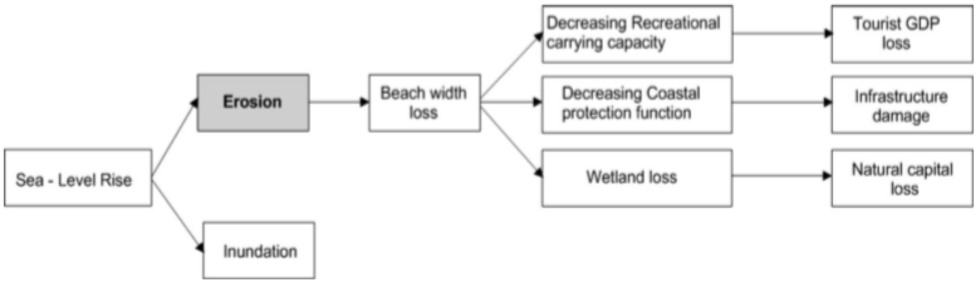

Figure 4.5 Impact of Sea Level Rise (SLR) induced erosion (Jiménez et al., 2017)

Due to its simplicity and ease of application, a 2-dimensional mass conservation principle known as Bruun Rule is used for prediction of landward and upward movement of cross-shore beach profile as a response to increase in mean sea level which is expressed by the following equation (Bruun 1954; Ranasinghe et al. 2007) as;

$$R = \Delta x \times \left(\frac{W_*}{B + h_*}\right) \tag{4.16}$$

Where, R is the shoreline retreat, Δx is the total sea level rise (SLR) in meters for a defined duration, B is the berm/dune height of the active beach in meters, W_* and ($B+h_*$) are the horizontal and vertical dimensions of the active profile respectively in meters. In other words, h_* is the active or closure depth (DOC) and W_* is the across-shore distance from B to h_*. The ratio of horizontal dimension of the beach to the vertical dimension of it can also be described as the averaged inner shelf slope of the beach to closure depth where significant profile changes are mainly observed (Jiménez et al. 2017; Rosati, Dean, and Walton 2013; Dean and Houston 2016; Atkinson et al. 2018).

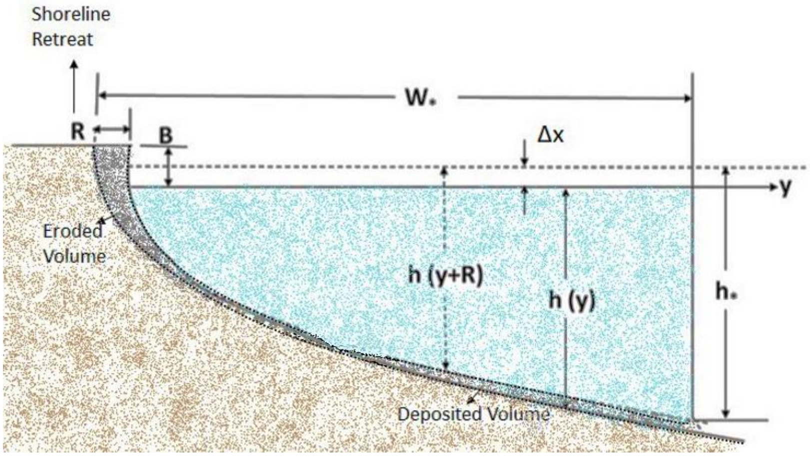

Figure 4.6 Characteristics of the Bruun Rule (Bruun 1954)

The assumptions made in Bruun Rule are as follows;

- The recession calculated by this rule is the beach erosion due to the landward translation of the beach profile cause by increase in mean sea level.
- The equilibrium between eroded and deposited volumes of beach profile is maintained between the upper beach and offshore.
- The rise in sea level is equal to the rise in nearshore bed slope as a result of deposition (applied as “rule of thumb” in engineering practices to show the relationship between shoreline retreat, R and nearshore beach slope, h_*/W_*) (Ranasinghe et al. 2007; SCOR 1991).
- The contribution of salinity in affecting the mass component, density and hence, the volume of the seawater and regional long-term sea level variability is assumed to be constant as well as the effect of atmospheric pressure and wind (known as meteorological components of sea level) (Gomis et al. 2012).

There are some limitations against these assumptions for Bruun Rule (Ranasinghe et al. 2007) as;

- Bruun Rule is only applicable at locations where beach profile is at equilibrium. Meanwhile, apart from small and/or seasonal fluctuations, there should not be any steepening or flattening for beach profile for Bruun Rule to be applicable.
- Bruun Rule is 2-Dimensional mass conservation principle which is used for prediction of net sediment displacement perpendicular to the shoreline without taking any longshore sediment transport (as sediment sinks or sources or alongshore gradients) parallel to the shoreline.
- Bruun Rule only covers up the sediment transport mechanisms perpendicular to the shoreline up to the depth of closure. It is assumed that there is no overwash, aeolian and/or offshore sand losses beyond the depth of closure.

- Bruun Rule is not applicable to areas including sediment sinks or sources and/or longshore sediment transport because of headlands or engineering coastal defense structures.
- Bruun Rule is only applicable to beaches having similar sediment properties across the beach profile and it is not valid for beaches with gravel sediment.

In this study, using various sea level rise projections (Alpar 2009; Vousdoukas et al. 2017) presented in Section 3.2.3, Bruun Rule (Bruun 1954) is applied to four beaches of Kuşadası as Pamucak, Kadınlar, Davutlar and Güzelçamlı which have similar sandy sediment properties all along the beach profile to measure the net sediment movement perpendicular the shore as a result of sea level rise. Also, along these four beaches, there are no/few coastal defense structures (1 to 2 structures in the quite long Davutlar and Güzelçamlı beaches) that may have a considerable impact on sediment sinks/sources and/or longshore transport. So, it can be assumed that the sediment transport perpendicular to the shore in these beaches is dominant which makes them suitable to apply Bruun rule. Since Dilek National Park have gravel type beaches, Bruun Rule can not be applied to calculate shoreline recession. The assumptions made in this thesis for the calculation of shoreline recession by this rule are as follows;

- Suspended sediment transport is not included.
- Regional longshore transport is assumed to be negligible.
- Combined cross and longshore sediment transports are assumed to be negligible.
- Shoreline response to existing wave climate variability is not included in this rule.
- Coastal structure may over or undereastimate the shoreline recession calculated by this rule because of the interactions with longshore and cross-shore transport (Rollason, Patterson, and Huxley n.d.). Yet, in this study there are no/few coastal defense structures along the beaches of the study area which

are assumed to have negligible impacts on sources/sinks and/or longshore and cross-shore sediment transports when compared to the sediment transport perpendicular to the shore.

Davutlar and Pamucak beaches are quite long beaches with different characteristics at each zone. Therefore, the calculations of DOC, shoreline change and RCC (using Bruun Rule) for these beaches are made for separate sections. For Pamucak beach the calculations are made for two sections of Pamucak-1 where there are mostly private seaside resorts, hotels and summerhouses and Pamucak-2 by the Küçük Menderes river where there are mostly public facilities nearby. For Davutlar beach the calculations are made for three sections of Davutlar-1 which is the nearest part of this beach to Güzelçamlı and it is wider than the other two section, Davutlar-2 as the middle zone where there are mostly private summerhouses and Davutlar-3 as the region with more human traffic because of the accessibility to the public facilities, restaurants and shopping places. The illustrations of these separate areas and Coordinates (Table 4.9) of beginning and ending of these areas are shown in following Figure 4.7 for Davutlar and Figure 4.8 for Pamucak beach.

Table 4.9 Start and end point coordinates of different sections of Pamucak and Davutlar beaches

Beach Section	*Start Point Coordinate*	*End Point Coordinate*
Davutlar-1 (D-1)	37.747° N, 27.252° E	37.774° N, 27.263° E
Davutlar-2 (D-2)	37.774° N, 27.263° E	37.794° N, 27.268° E
Davutlar-3 (D-3)	37.794° N, 27.268° E	37.812° N, 27.269° E
Pamucak-1 (P-1)	37.922° N, 27.276° E	37.941° N, 27.275° E
Pamucak-2 (P-2)	37.942° N, 27.275° E	37.955° N, 27.267° E

Figure 4.7 Coordinates of D-1, D-2 and D-3 (Google Earth, 2019)

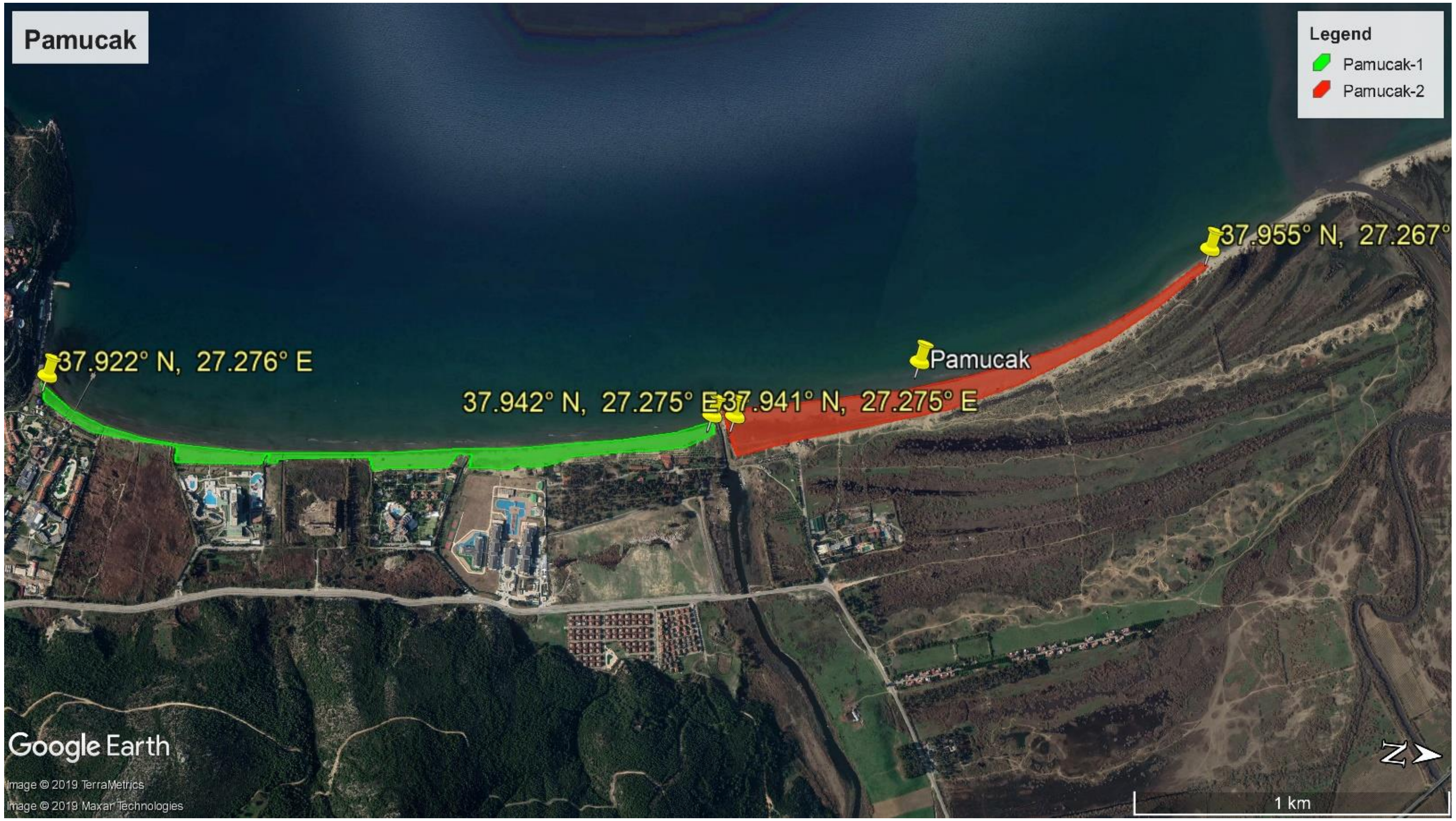

Figure 4.9 Coordinates of P-1, P-2 and P-3 (Google Earth, 2019)

Depth of Closure Calculation

Depth of closure can be defined as the depth beyond which there is no significant bed-profile changes detected or the morphological change is negligible described as lower shoreface. In this study, it is assumed that there is no/negligible bed load sediment transportation and any other morphological change as a result of extreme wave conditions. There are several ways for the estimation of depth of closure either by using mathematical formulations or through profile surveys and observations of morphological data (collected over several years at least and costly to obtain) (Nicholls et al. 2015; Aragonés et al. 2018; Valiente et al., 2019). In this study, two approaches are used to determine depth of closure.

First approach is based on Jiménez et al. (2017). They assumed that the depth beyond which the morphological actions are relatively non-active is approximately 10 meters where the impacts of sea level rise is observed more. So, 10 meters depth is used individually as a depth of closure.

Second approach is calculating the depth of closure using mathematical formulations of Hallermeier (1981, 1983), and Birkemeier (1985) which is a modified Hallermeiers expression because of its overpredicted estimations (about 25%) (Valiente et al. 2019) (Equation 4.17 and 4.18).

- Hallermeier (1981) formula for calculation of DOC;

$$DOC_{Hallermeier} = (2.28 \times H_{s,12}) - (68.5 \times \frac{{H_{s,12}}^2}{g \times {T_s}^2}) \qquad (4.17)$$

- Birkemeier (1985) formula for calculation of DOC;

$$DOC_{Birkemeier} = (1.75 \times H_{s,12}) - (57.9 \times \frac{{H_{s,12}}^2}{g \times {T_s}^2}) \qquad (4.18)$$

Where, $Hs_{,12}$ is the 12 hours exceeded significant wave height in meters, T_s is wave period in seconds, g is gravitational acceleration as 9.81 m/s^2. Data for $Hs_{,12}$ and T_s was determined from wind and wave climate study performed for Kuşadası and transforming the deep water wave heights to near shore (10m water depth as suggested in Stive 2004; Wise n.d.; Jiménez et al. 2017) with SWAN model.

Required wave parameters ($H_{s,12}$ & T_s) were obtained using SWAN (Simulating Waves Nearshore) which is a third-generation wave model used for realistic estimations of wave parameters in coastal areas on the coarse or fine grid with specified wind and bathymetry data. The 12 hours exceeded significant waves from S, SSW, SW, WSW, W, WNW, NW, NNW and N directions were transported nearshore and the wave parameters data in transects perpendicular to the shore at depth of 10 meter were obtained using ISOline command in SWAN and the average wave heights and periods were calculated. The input data used for SWAN run are as follows;

- Deep water, 12 hours/year exceeded wave parameters given in Table 3.4.
- x-direction coordinate from origin x, N 37.6 to 38.1
- y-direction coordinate from origin y, E 26.8 to 41
- Non-linear four-wave interactions (quadruplets) and dissipation by whitecapping are not included.

The depths of closure are calculated using highest wave parameters from dominant directions for each beach as presented in Table 4.10. The distances from $DOC_{Hallermeier}$, $DOC_{Birkemeier}$ and 10 meters depth to the berm height of each beach are measured in decimal degrees (dd) using Surfer from the elevation data obtained (EMODnet Bathymetry, 2019). The calculated DOCs with both Hallermeier (1981) and Birkemeier (1985) are mostly between 1-1.5 meters depth where it is assumed that most of the morphological changes are taking place and impact of sea level rise will be mostly seen.

Table 4.10 Depth of Closure of Hallermeir (1981) and Birkemeier (1985) and distance between DOC and berm height

Beach	*P-1*	*P-2*	*Kadınlar*	*D-1*	*D-2*	*D-3*	*Güzelçamlı*
H_s, m	0.83	0.80	0.81	0.66	0.72	0.71	0.51
Dominant Direction	SW	SW	WSW	WNW	WNW	WNW	W
T_s, s	3.95	3.94	3.77	3.33	3.31	3.31	3.32
$DOC_{Hallermeier}$	1.58	1.53	1.53	1.23	1.31	1.29	1.00
Distance of $DOC_{Hallermeier}$ to B, dd	0.0023	0.0033	0.0072	0.0009	0.0009	0.0013	0.0002
$DOC_{Birkemeier}$	1.19	1.15	1.15	0.92	0.98	0.97	0.76
distance of $DOC_{Birkemeier}$ to B, dd	0.0021	0.0029	0.0067	0.0008	0.0007	0.0012	0.0001
Distance d*=10m to B, dd	0.0124	0.0097	0.0129	0.0036	0.0050	0.0072	0.0022

Available Beach Area for Future RCC

Using the calculated DOC of each beach, SLR values of different scenarios (RCP 4.5, RCP 8.5 and Mentes station), berm heights and vertical and horizontal dimensions of active beach profiles, shoreline retreats for each beach are calculated using Bruun Rule (Equation 4.16) for the next 25, 50, 75 and 100 years. These retreat values are used to determine the percentages of beach width changes after 25 years (Table 4.11 and Table 4.15), 50 years (Table 4.12), 75 years (Table 4.13) and 100 years (Table 4.14) since 2000. The positive percentages show the percentage of the beach width available after shoreline retreat. The negative percentages show that there will be no beach area available because of erosion.

According to results presented in Table 4.11 most of the Kadınlar beach will be lost as a result of SLR even with the best-case scenario (RCP 4.5) until 2025 which is compatible with the results obtained with Menteş projection (Table 4.12). Decrease in beach widths will be obviously seen in Pamucak and northern parts of Davutlar (D-2 and D-3) as a result of SLR until 2050 while there will be a slight decrease in beach width of Güzelçamlı even until 2075. In coming 100 years, Pamucak, Kadınlar and most of the northern parts of Davutlar beaches will be lost as a result of SLR as it is presented in Table 4.14.

Table 4.11 Available percentage of beach width after applying SLR projections (2000-2025)

	SLR, m	*P-1*	*P-2*	*Kadınlar*	*D-1*	*D-2*	*D-3*	*Güzelçamlı*
RCP 8.5 (2000-2025) & $\Delta x_{\text{Hallermeier}}$	*0.1*	83.46	87.26	-17.57	94.00	87.06	82.12	98.94
RCP 4.5 (2000-2025) & $\Delta x_{\text{Hallermeier}}$	*0.08*	86.76	89.81	5.94	95.20	89.64	85.70	99.15
RCP 8.5 (2000-2025) & $\Delta x_{\text{Birkemeier}}$	*0.1*	82.84	87.34	-24.15	94.00	88.28	81.77	99.54
RCP 4.5 (2000-2025) & $\Delta x_{\text{Birkemeier}}$	*0.08*	86.27	89.88	0.68	95.20	90.63	85.41	99.63
RCP 8.5 (2000-2025) & Δx with DoC=10 m	*0.1*	74.10	79.81	73.16	92.52	89.65	84.95	95.42
RCP 4.5 (2000-2025) & Δx with DoC=10 m	*0.08*	79.28	83.85	78.52	94.02	91.72	87.96	96.34

Table 4.12 Available percentage of beach width after applying SLR projections (2000-2050)

	SLR, m	*P-1*	*P-2*	*Kadınlar*	*D-1*	*D-2*	*D-3*	*Güzelçamlı*
RCP 8.5 (2000-2050) & $\Delta x_{\text{Hallermeier}}$	*0.24*	60.29	69.43	-182.17	85.59	68.93	57.09	97.45
RCP 4.5 (2000-2050) & $\Delta x_{\text{Hallermeier}}$	*0.2*	66.91	74.52	-135.14	87.99	74.11	64.24	97.88
RCP 8.5 (2000-2050) & $\Delta x_{\text{Birkemeier}}$	*0.24*	58.81	69.63	-197.95	85.60	71.88	56.24	98.89
RCP 4.5 (2000-2050) & $\Delta x_{\text{Birkemeier}}$	*0.2*	65.68	74.69	-148.29	88.00	76.57	63.53	99.07
RCP 8.5 (2000-2050) & Δx with DoC=10 m	*0.24*	37.84	51.54	35.57	82.06	75.16	63.88	89.01
RCP 4.5 (2000-2050) & Δx with DoC=10 m	*0.2*	48.20	59.62	46.31	85.05	79.30	69.90	90.84

Table 4.13 Available percentage of beach width after applying SLR projections (2000-2075)

	SLR, m	*P-1*	*P-2*	*Kadınlar*	*D-1*	*D-2*	*D-3*	*Güzelçamlı*
RCP 8.5 (2000-2075) & $\Delta x_{\text{Hallermeier}}$	*0.45*	25.55	42.67	-429.06	72.99	41.75	19.55	95.23
RCP 4.5 (2000-2075) & $\Delta x_{\text{Hallermeier}}$	*0.38*	37.13	51.59	-346.76	77.19	50.81	32.06	95.97
RCP 8.5 (2000-2075) & $\Delta x_{\text{Birkemeier}}$	*0.45*	22.77	43.05	-458.66	73.00	47.28	17.95	97.91
RCP 4.5 (2000-2075) & $\Delta x_{\text{Birkemeier}}$	*0.38*	34.78	51.91	-371.76	77.20	55.48	30.72	98.23
RCP 8.5 (2000-2075) & Δx with DoC=10 m	*0.45*	-16.55	9.14	-20.80	66.36	53.43	32.27	79.39
RCP 4.5 (2000-2075) & Δx with DoC=10 m	*0.38*	1.58	23.27	-2.01	71.59	60.68	42.81	82.60

Table 4.14 Available percentage of beach width after applying SLR projections (2000-2100)

	SLR,m	*P-1*	*P-2*	*Kadınlar*	*D-1*	*D-2*	*D-3*	*Güzelçamlı*
RCP 8.5 (2000-2100) & $\Delta x_{\text{Hallermeier}}$	*0.8*	-32.35	-1.91	-840.55	51.98	-3.56	-43.03	91.51
RCP 4.5 (2000-2100) & $\Delta x_{\text{Hallermeier}}$	*0.52*	13.97	33.76	-511.36	68.79	32.69	7.03	94.48
RCP 8.5 (2000-2100) & $\Delta x_{\text{Birkemeier}}$	*0.8*	-37.30	-1.25	-893.18	52.00	6.27	-45.86	96.28
RCP 4.5 (2000-2100) & $\Delta x_{\text{Birkemeier}}$	*0.52*	10.76	34.19	-545.57	68.80	39.08	5.19	97.58
RCP 8.5 (2000-2100) & Δx with DoC=10 m	*0.8*	-107.20	-61.53	-114.76	40.19	17.21	-20.41	63.36
RCP 4.5 (2000-2100) & Δx with DoC=10 m	*0.52*	-34.68	-4.99	-39.59	61.12	46.19	21.74	76.19

Table 4.15 Available percentage of beach width after applying SLR projections of Menteş (2000-2025)

	SLR, m	*P-1*	*P-2*	*Kadınlar*	*D-1*	*D-2*	*D-3*	*Güzelçamlı*
Mentes (1986-2001) & $\Delta x_{\text{Hallermeier}}$	*0.155*	74.36	80.25	-82.23	90.70	79.94	72.29	98.36
Mentes (1986-2001) & $\Delta x_{\text{Birkemeier}}$	*0.155*	73.40	80.38	-92.43	90.70	81.84	71.74	99.28

CHAPTER 5

RESULTS AND DISCUSSION

5.1. Beach Carrying Capacity Assessment of Beaches

The Cifuentes (1992) method, which measures the carrying capacity of natural protected areas, was adapted and applied to three urban beaches (Kadınlar, Davutlar and Güzelçamlı), a non-urban beach (Pamucak) and four natural beaches in Dilek Peninsula National Park (Karasu, Aydınlık, Kavaklıburun and İçmeler) in Kuşadası region. By considering the areas available for recreational use in the beaches, the comfort conditions for visitors and the climatic and geomorphological characteristics of the region that have changed over the years, the physical and real carrying capacity for each beach have been calculated following the steps shown in Figure 5.1.

In this chapter, the results of present and future beach carrying capacity assessment is presented. Present BCC values are examined in light of field observations. Finally, sustainability of Kuşadası beaches is discussed considering the present and future RCC values.

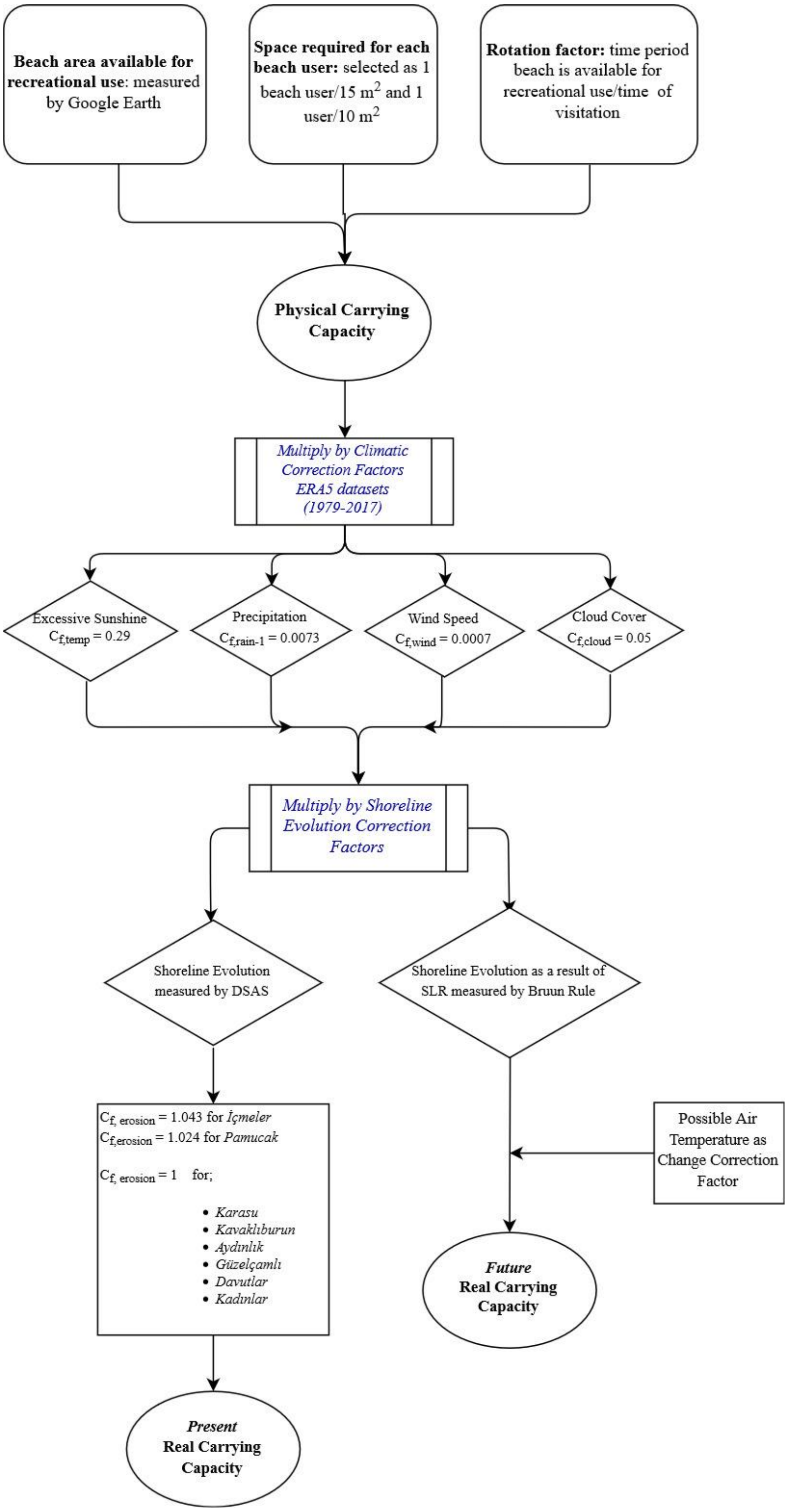

Figure 5.1 Steps of BCC assessment in this study

5.1.1. Physical Carrying Capacity Assessment

The total available area for recreational use and the rotation factor for each beach to calculate the physical carrying capacities is presented in Table 5.1.

Table 5.1 Required Parameters for Calculation of Physical Carrying Capacities of Beaches

Beach	*Total available area, m^2*	*Rotation factor*
Karasu	7283	1
Kavaklıburun	7820	1
Aydınlık	11691	1
İçmeler	4221	1
Güzelçamlı	79540	2.25
Davutlar	242223	2.25
Kadınlar	9987	2.25
Pamucak	189185	1

PCC of the beaches are calculated using two different available space for each person as 10 and 15 m^2 as it was discussed in Chapter 4. This parameter may vary based on comfort perception of beach users and in some of the beaches according to the available area for each user; hence, the ideal PCC values for beaches may vary based on this parameter which can also be judged according to the PCC results presented in Table 5.2. The values in Table 5.2 indicates the total number of visits possible in a day for each beach when visitors consider a certain available space as their tolerance to crowding. As their tolerance to crowding increases (i.e. they are comfortable with sharing a closer space with others), PCC of beaches increases accordingly. Higher PCC values indicate intense use of beach and its resources.

Table 5.2 Physical Carrying Capacities of beaches (number of visits in a day)

Beach	*PCC with 15m^2 available space for each user, person*	*PCC with 10m^2 available space for each user, person*
Karasu	486	728
Kavaklıburun	521	782
Aydınlık	779	1169
İçmeler	281	422
Güzelçamlı	11931	17897
Davutlar	36333	54500
Kadınlar	1498	2247
Pamucak	12612	18919

The PCC values which show the maximum number of visitors at the same time are also presented in Table 5.3.

Table 5.3 Physical Carrying Capacities of beaches at the same time (numberof people at the same time)

Beach	*PCC at the same time (for Z/a=1/15), person*	*PCC at the same time (for Z/a=1/10), person*
Karasu	486	728
Kavaklıburun	521	782
Aydınlık	779	1169
İçmeler	281	422
Güzelçamlı	5303	7954
Davutlar	16148	24222
Kadınlar	666	999
Pamucak	12612	18919

As it was mentioned in the previous chapter of this study, since the rotation factors for beaches of Dilek National Park (Karasu, Kavaklıburun, Aydınlık, İçmeler) and Pamucak is assigned as 1, the maximum number of people that can occupy the beach at the same time is the same as the PCC which is the maximum number of visits for a beach in a day. Yet, this is not the case all the time. As I have observed during the field survey, people with entrance tickets to Dilek National Park may leave the park whenever they desire and come back to the beaches many times with their tickets until 17:00. However, since the capacity of beaches are not as much as the urban beaches such as Güzelçamlı and Davutlar, because of the limited number of benches and parking lots available beside the beaches and the long roads to arrive to beaches, people usually tend to stay inside the national park. Also, for Pamucak beach the assumption of rotation factor being 1 seems also logical because of two main reasons. Pamucak is relatively far from the city center and people with personal vehicles usually tend to visit this beach and they prefer to stay and use the beach once per day. Secondly, most of the people using this beach are staying at hotels across this beach using the beach continually from morning until evening only giving short meal breaks. Therefore, for those beaches which are already assigned rotation factor as 1 are limited with their physical boundaries in terms of number of visits in a day. Although this approach might seem conservative, for many of these beaches once an area is occupied, it is occupied for the rest of the day. Thus, a second visit to the same area is not possible.

5.1.2. Real Carrying Capacity Assessment

The summary table of climate correction factors obtained in Chapter 4 (using air temperature, precipitation, total cloud cover and wind speed ERA5 datasets) is presented in the Table 5.4.

Table 5.4 Climatic correction Factors (Cf) of Kuşadası region

Excessive Sunshine, Cf_{temp}	*Total Cloud Cover, $Cf_{cloudliness}$*	*Precipitation>1 mm/hour, Cf_{rain-1}*	*Precipitation>2 mm/hour, Cf_{rain-2}*	*Wind, Cf_{wind}*
0.29	0.05	0.0073	0.0034	0.0007

The physical carrying capacity of each beach is multiplied by climatic correction factors to represent the capacities with climatic limitations (Table 5.5). The effect of precipitation is relatively low for Kuşadası region, since the time period with rainfall in Kuşadası is very low. Therefore, the difference between rainfall intensities considered in this study as 1 and 2 mm/hour is negligible while calculating the PCCs. Hence, the precipitation correction factor of hourly duration with intensities higher than 1 mm/hour as $Cf_{rain-1} = 0.0073$ is decided to be used for rest of the calculations.

Table 5.5 Real Carrying Capacities of beaches (beach carrying capacities corrected by climatic factors), person

Beach	*RCC (Z/a=1/15), person*	*RCC (Z/a=1/10), person*
Karasu	322	483
Kavaklıburun	346	519
Aydınlık	517	776
İçmeler	187	280
Güzelçamlı	7917	11875
Davutlar	24108	36162
Kadınlar	994	1491
Pamucak	8369	12553

According to the results, the carrying capacities of beaches are decreased by ratio of two thirds and the effect of temperature on decreasing the PCCs are significantly important when compared to other correction factors. Total cloud cover has also a considerable effect on decreasing the PCCs of beaches but not as much as temperature. When comparing the different results for specified spaces available for each beach users, the effect of them on carrying capacity assessment is considerably high. As the space available for each user decrease, the PCC and RCC of beaches increase proportionally. Wind correction factors has the least almost no effect on changing the PCCs.

Afterwards, erosion/accretion correction factor obtained by DSAS was applied respectively as well as the other climatic correction factors to obtain the real carrying capacities of the beaches for the present and very near future (<10 years). As the DSAS erosion correction factor, weighted linear regression rates were used in order to take the uncertainty of datasets into account (Table 4.7). The RCC values for each beach are presented in Table 5.6. The RCC values for upper and lower bounds of WLR factors are presented in Appendix-B.

Table 5.6 Real Carrying Capacities of beaches (corrected by climatic factors + DSAS-WLR erosion/accretion correction factors)

Beach	*RCC (Z/a=1/15), person*	*RCC (Z/a=1/10), person*
Karasu	322	482
Kavaklıburun	346	518
Aydınlık	517	766
İçmeler	195	292
Güzelçamlı	7817	11819
Davutlar	24108	36482
Kadınlar	994	1496
Pamucak	8567	12850

The real carrying capacities of Pamucak and İçmeler increased after applying the erosion/accretion correction factors since the average WLR rates measured using DSAS tool were accretional for these beaches. Yet, the difference is still too low for especially İçmeler. The situation for Karasu, Kavaklıburun, Aydınlık and Güzelçamlı are the opposite and since the WLR rates are erosional but insignificant; therefore, the correction factor was taken as 1 such that no change in RCCs will be expected in the near future. The calculated shoreline evolution rates of beaches are very low considering the spatial resolution of these images (lower than 2 meters for 2004-2010 years) (Satellite Imaging Corporation 2017) and the possible uncertainties while digitizing the shorelines in Google Earth. So, the effect of shoreline evolution in the near future can be considered as insignificant for beaches of Kuşadası with assumptions made in this study.

5.1.3. Field Survey Results and Discussions

Based on the number of beach users recorded for a specific time period and considering the calculated ideal carrying capacity of each beach, it can be roughly estimated whether the beach is exceeding its capacity or not. The real carrying capacity of each beach is a maximum number visit in a day during the tourism season considering the correcting and limiting factors of that site. So, although the field observations took place for a short amount time and did not cover the whole day, if the number of beach users recorded in field survey are exceeding this real capacity in a shorter time period, it is highly possible that daily number of visit would exceed RCC capacity at the end of the day. Therefore, even if field survey results cannot be representative for the whole tourism season, a comparison with calculated RCC values could provide insight into the level of sustainability of these beaches for any random day.

As mentioned in Section 3.2.4, there were some additional considerations on the data collected during field observations. The most important of these is the number of people in the sea at the time of the data collection. As the focus was on the number of beach users located at the beach at the time of the field survey, an accurate number of people in the sea could not be determined from the video recordings. Therefore, based on my observations at the field, it is assumed that for all of the beaches, as 20% of the counted number of people sitting on the beach were also in the sea. So, the number of beach users at the same time are re-calculated as presented in Table 5.7.

Table 5.7 Number of beach users according to field observations with addition of people in the sea, person

Beach	*Saturday*		*Monday*
	Noon	*Evening*	
Karasu	386		420
Kavaklıburun	420		264
Aydınlık	180		396
İçmeler	304		280
Güzelçamlı	2230	1718	1586
Davutlar	1496	1090	2549
Kadınlar	952	408	1950
Pamucak	-		509

Kadınlar beach and three of the beaches of Dilek National Park were being used by at their calculated real carrying capacities at the time of the field observations (which are valid for short duration) as presented in Table 5.8. Considering the possible increase in this number later in the day, it is expected that the beaches possibly exceeded their carrying capacity limits for the observation days. In these beaches people actually do not have a chance to set a larger area for themselves apart, they settle for a smaller area as 5-10 m^2, whereas the general guidelines for visitor comfort determines this area as at least 10 m^2 for each beach user.

Table 5.8 Field observations and calculated PCC and RCC for Kuşadası Beaches

Beach	*Users at the same time*	*PCC (1/10 m2)*	*RCC (1/10m2)*	*Saturday*	*Monday*
Karasu	728	728	482	386	420
Kavaklıburun	782	782	518	420	264
Aydınlık	1169	1169	766	180	396
İçmeler	422	422	292	304	280
Güzelçamlı	7954	17897	11819	2230-1718	1586
Davutlar	24222	54500	36482	1496-1090	2549
Kadınlar	999	2247	1496	952-408	1950
Pamucak	18919	18919	12850	3790	509

Based on the results given in Table 5.8, it is obvious that Kadınlar beach is exceeding its physically tolerable carrying capacity. So, during the day with more people visiting the beach, the tolerable capacity may be certainly exceeded. The physical carrying at the same time calculated are near to the number of users counted at field for Kadınlar beach; so, users are forced to use smaller areas as 5 m^2 on the beach. For beaches of Dilek National Park the number of beach users counted at fields for a short time is also high and with increasing number of entrances to national park during the day it may exceed the physically tolerable capacity of beaches until later hours in the evening. The entrances to these beaches is already limited during the day; yet, it may be better to limit usage of these beaches and the entrance of vehicles to this natural area; so that, the sustainability and conservation of these beaches can be maintained.

5.2. Climate Change and Future Carrying Capacity Assessment

Scenarios of different climate models should be analyzed and adapted to the study area in order to see the impacts of predicted climate change. When high-resolution climate model projections are accessible and sectors use these data in adaptation, prevention and mitigation plans, the accuracy and success of their work will also increase. In this section, climate change projections integrated into RCC is presented as BCC of beaches in future.

5.2.1. Future RCC with SLR Projections

Accelerated rise in global sea level have been considered as the most important impact of climate change for many years according to Church et al. (2013). When global average sea level changes are analyzed, sea levels will continue to rise during the 21st century as around 1 meter by the year 2100 and the current rise rate is estimated to be 3 to 10 times faster by then (Church et al. 2013).

In all RCP scenarios, it is reported that this increase will most likely cause by warming in the oceans and melting in glaciers (addition/removal of mass component). (Akçakaya et al. 2015). And this rise, could increase storm surges, flooding, inundation and damage to properties and environment and hence decrease the value of the coastal zones (Gilbert and Vellinga 1992; Church et al. 2013).

Carrying capacities of beaches are corrected by erosion factors coming from sea level rise projections during 2000-2100 years with 25-year intervals in the RCC calculations instead of DSAS approach. The results are presented as the graphs of RCC of each beach versus time in this section. The detailed results are tabulated in Appendix-C. For the beaches where the whole width of beach is retreated, the RCC value is going to be 0. The calculations are made similarly for combinations of RCP 4.5 and RCP 8.5 with shoreline retreats measured using depths of closures calculated by Hallermeier and Birkemeier formulas (Equation 4.17 and 4.18) and 10 meters. The lowest and highest RCCs of each beach are also calculated using the lower and upper confidence levels of sea level rise scenarios presented in the following figures.

In the first section of Pamucak (P-1) beach (Figure 5.2) where there are mostly private hotels, the real carrying capacity of beach will decrease from 3649 person to around 3400 in the best case and around 2500 people with the worst case SLR scenario after 25 years. Considering the current usage density of this beach based on the field observations, SLR is not expected to affect the usability drastically until 2050. However, the negative impacts of SLR on decreasing the beach width is clearly seen with these trends in the long run.

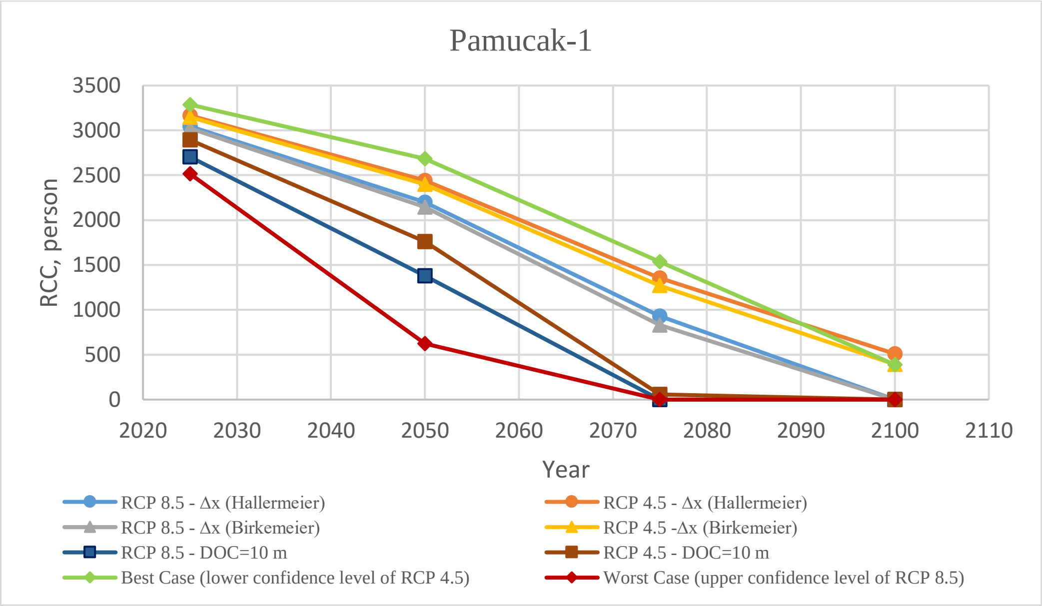

Figure 5.2 RCC of P-1 section of Pamucak beach using Bruun Rule

As it is observed in the Figure 5.2, the results of carrying capacities calculated with both depths of closure of Hallermeier and Birkemeier formulas are nearly similar. The Birkemeier which is a modified expression of Hallermeier formula, estimates lower values since the Hallermeier depths of closure were mentioned by Birkemeier to be

25% over-predicted. Yet, the difference is negligible for this capacity results. However, the results of RCC calculated using 10 meters of depth closure are relatively low. Since, the upper shoreface where there are morphological changes detected, is larger in case of 10 meters than $DOC_{Hallermeier}$ & $DOC_{Birkemeier}$ (approximately 1.5-2 meters), SLR rise impact on decreasing the RCC's would be higher for Pamucak-1. Figure 5.3 shows the bed slope in section P-1 of Pamucak beach (Elevation/depth of water is in meters and distance of shoreline is in decimal degrees).

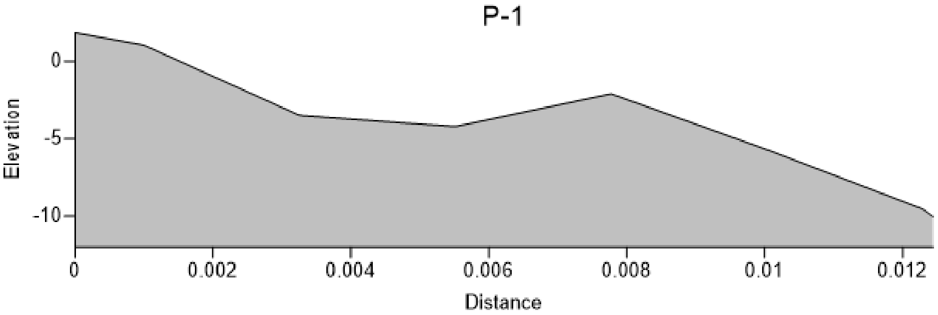

Figure 5.3 Bed slope in P-1 plotted with Surfer using EMODnet bathymetry data (2019)

In the second section of Pamucak (P-2) beach (Figure 5.4) near to the public entrance of the beach, the real carrying capacity of beach will decrease from 4719 person to around 3900 in the best case and around 2800 people with the worst case SLR scenario after 25 years and to 2000 people with the best case scenario after 100 years. This section of Pamucak beach which is near Küçük Menderes river is relatively wider than the P-1 section possibly because of the sediment transport from this river; so, SLR trends is not expected to be a serious threat at least for the touristic activities until 2080.

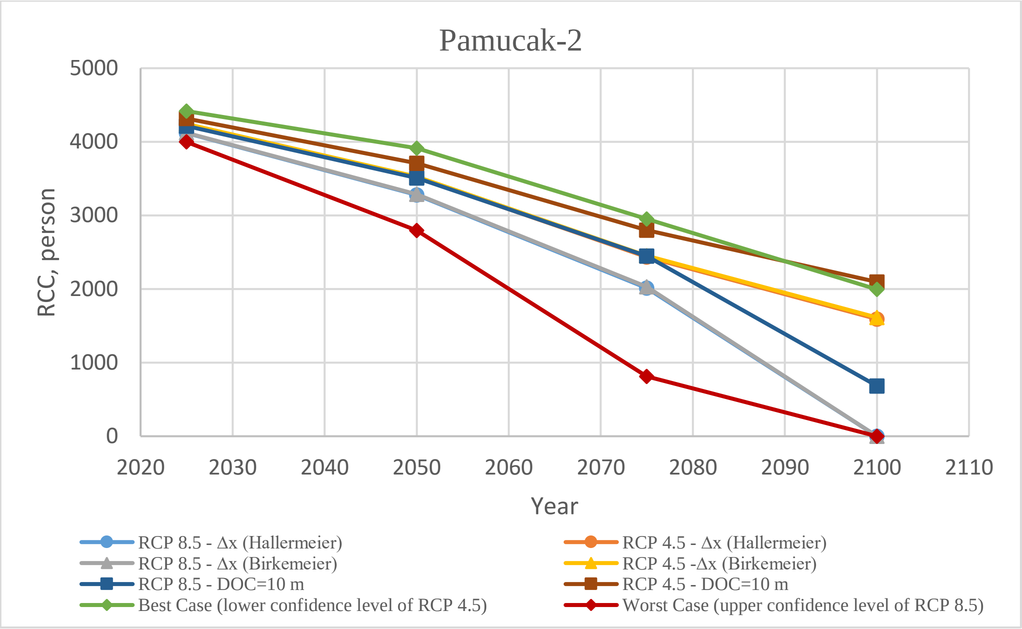

Figure 5.4 RCC of P-2 section of Pamucak beach using Bruun Rule

The results of RCC calculated using 10 meters of depth closure, $DOC_{Hallermeier}$ & $DOC_{Birkemeier}$ are relatively close. Since, this section of Pamucak beach is gently sloping toward deep sea (Figure 5.5) because of the sediment transport from the nearby creek at the northern parts of the beach, this is reflected in the RCC calculations as a milder change due to sea level rise.

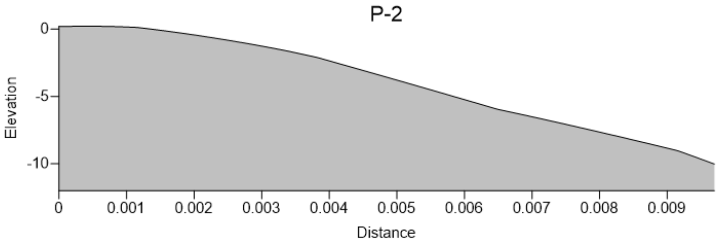

Figure 5.5 Bed slope in P-2 plotted with Surfer using EMODnet bathymetry data (2019)

For Kadınlar beach (Figure 5.6) with the estimated sea level rise projections, the RCC of the beach will fall to nearly zero with even the best-case scenario of SLR after only 50 years. Because of the concrete wall behind the beach, there will be no room for the beach to go back. So, it can be said that this is enough reason for urgent warning to maintain the sustainability of this beach.

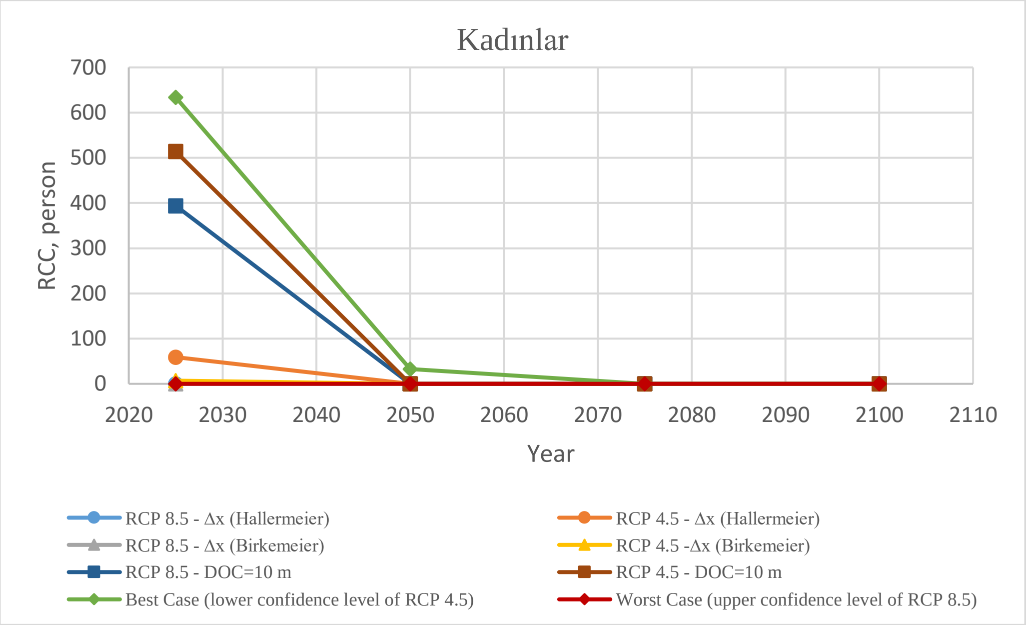

Figure 5.6 RCC of Kadınlar beach using Bruun Rule

The graph of bed slope for Kadınlar with a gradually decreasing slope is given in the following Figure 5.7.

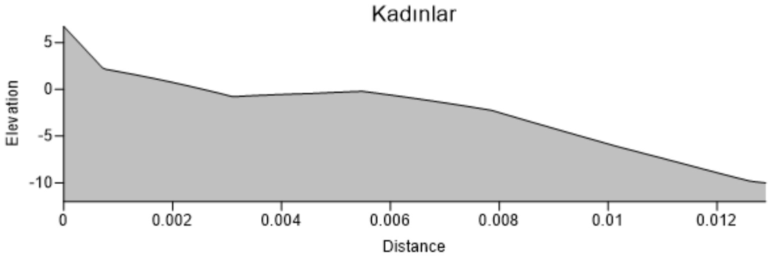

Figure 5.7 Bed slope in Kadınlar plotted with Surfer using EMODnet bathymetry data (2019)

For Davutlar beach, the RCC of D-2 (Figure 5.9) and D-3 (Figure 5.10) as the northern parts of the beach will drop to half of their capacities calculated in present day after nearly 75 years with average SLR scenarios. D-3 section of Davutlar, will disappear relatively faster than the other sections. Because of its close distance to the center parts of Kuşadası and more convenient accessibility for public users, the human-induced effects may also contribute to decrease of RCC. In D-1 section of Davutlar (Figure 5.8) and Güzelçamlı (Figure 5.11) which is beside it, there will be a slight decrease in RCC values since the beach widths are relatively wider than others.

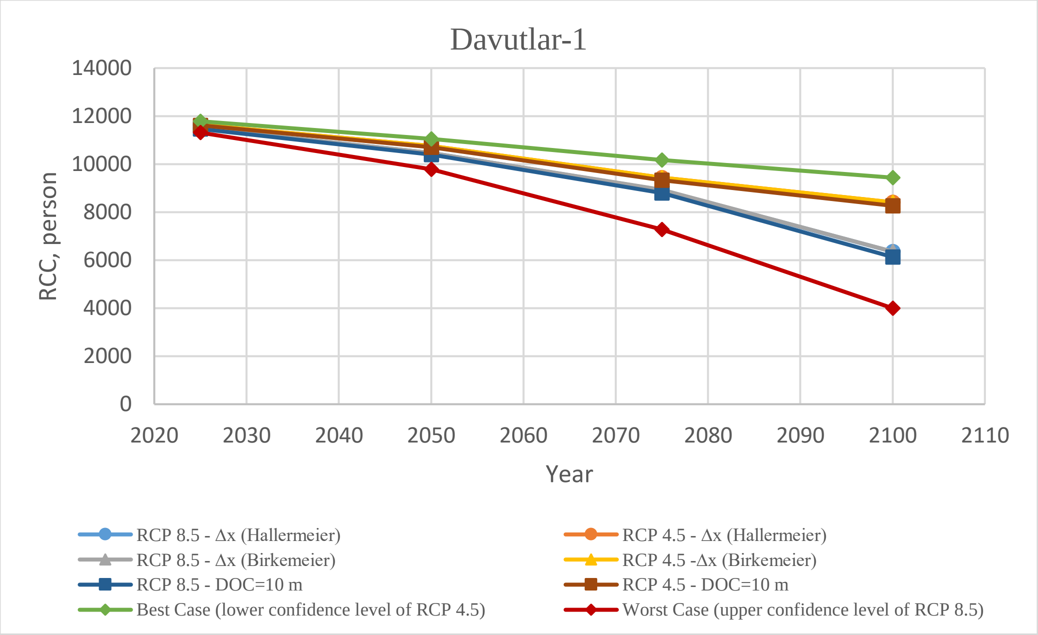

Figure 5.8 RCC of D-1 section of Davutlar beach using Bruun Rule

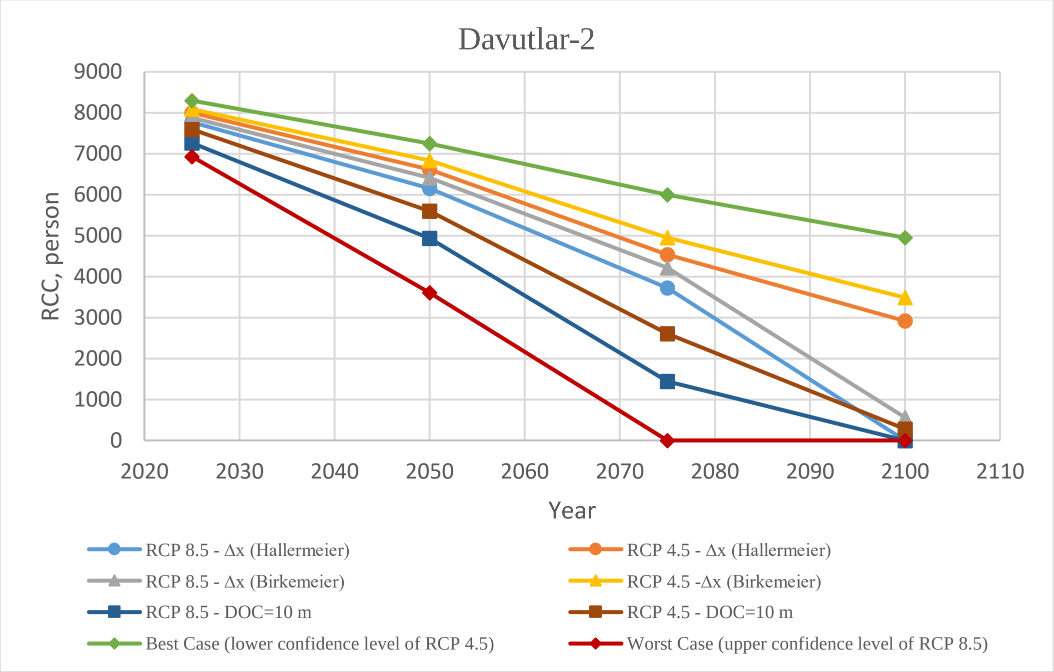

Figure 5.9 RCC of D-2 section of Davutlar beach using Bruun Rule

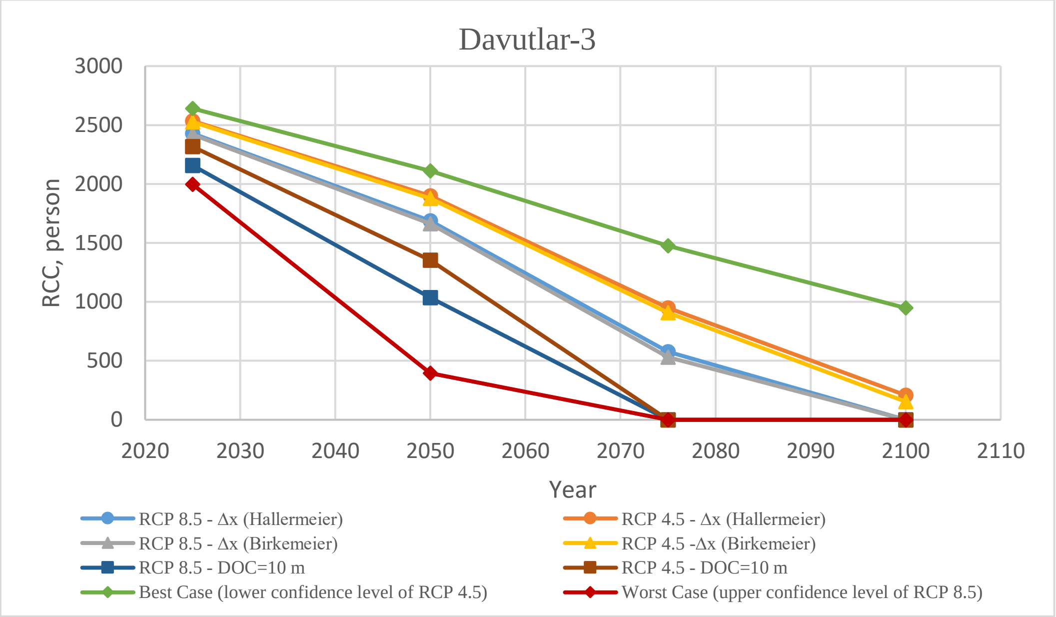

Figure 5.10 RCC of D-3 section of Davutlar beach using Bruun Rule

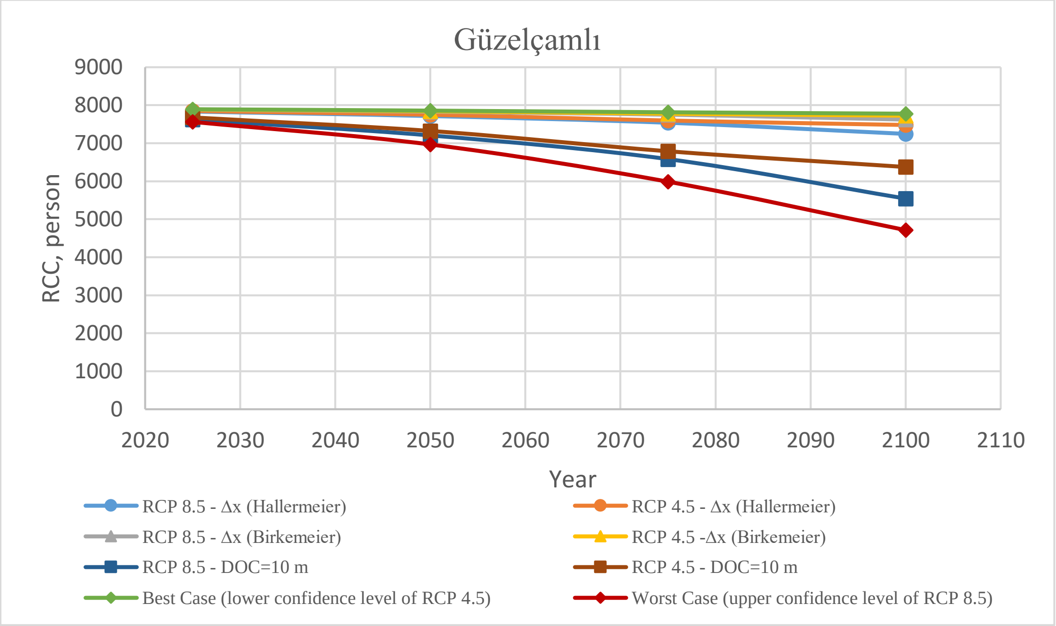

Figure 5.11 RCC of Güzelçamlı beach using Bruun Rule

Beach slopes are not changing along the different sections of Davutlar (Figure 5.12) and Güzelçamlı beaches and intermediate slope is dominant mostly except for D-3 (close to Güzelçamlı), in which a sudden change in bed slope is observed resulting in more plunging waves in this region.

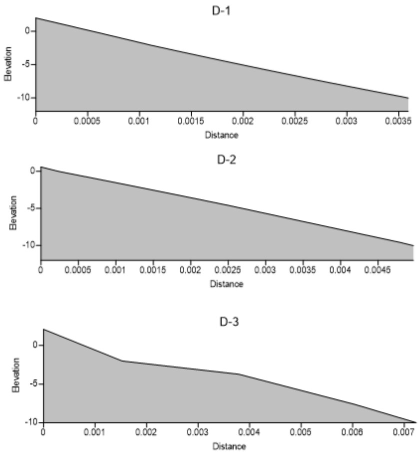

Figure 5.12 Bed slope in Davutlar plotted with Surfer using EMODnet bathymetry data (2019)

The RCCs of beaches calculated using the Menteş SLR data (Table 5.9) are quite close to the results of RCC with RCP 8.5 projection during 2000-2025 years. According to the obtained results with different SLR scenarios and different assumptions for calculation of depths of closure, Kadınlar beach is the first beach to be lost. In the next 50 years, the whole beach will be retreated, and it will be no longer usable. Since there is a concrete wall behind the coast with nearly 6 meters height, there will be no place for beach to go back any further than this. In the next 100 years, other beaches such as Pamucak and Davutlar will disappear too; if the sea level rises as the SLR scenarios. For Pamucak and Davutlar, it is observed that the sections of entrance of the beach as P-1 and D-3 will disappear quicker and as it goes toward the northern parts of Pamucak, where there are more private facilities and hotel and northern parts of Davutlar (D-1) towards Güzelçamlı, the beach widths decrease slower.

Table 5.9 RCC of beaches using Menteş SLR data

	SLR, m	*P-1*	*P-2*	*Kadınlar*	*D-1*	*D-2*	*D-3*	*Güzelçamlı*
Mentes (1986-2001) & Δx(Hallermeier, 1985)	0.155	2713	3788	817	11088	7134	2138	7786
Mentes (1986-2001) & Δx(Birkemeier, 1981)	0.155	2678	3794	919	11088	7304	2122	7860

5.2.2. Future RCC with SLR and Temperature Projections

Correction factors were determined as 0.458 for best-case (+1.5°C), 0.651 for average increase (+3°C) and 0.994 for the worst-case scenario (+5°C) of temperature rise in Section 3.2.3.1. The RCC of beaches were corrected by temperature rise correction factors as presented in Table 5.10.

Table 5.10 Summary table of RCCs of beaches by applying both SLR and temperature rise scenarios

Beach	*Present RCC*	*Future RCC with average SLR projection &* $\Delta x_{Hallermeier}$	*Future RCC with SLR & average temperature rise projection*
P-1	3649	3166	1105
P-2	4719	4238	1479
Kadınlar	994	59	21
D-1	12225	11638	4062
D-2	8925	8001	2792
D-3	2958	2535	885
Güzelçamlı	7917	7849	2739

SLR and resulting shoreline evolution is an impact limiting or expanding the physical dimensions of available beach area for recreational use; so, it may have a direct impact on decreasing or increasing the maximum limit that a beach can tolerate physically. Yet, the climatic factors such as temperature determines the limits that beach users can tolerate. This means that with this trend of temperature rise, after 75-100 years, beach users need to adapt their comfort levels about using the beaches at temperatures of higher than 30-35°C; otherwise, there would be an extreme drop in number of beach users especially for Kadınlar beach.

5.3. Discussion of BCC Results in the Light of Sustainable Management

According to Clark (1996), Salerno (2013), United Nations World Tourism Organization (2015), Sridhar et al. (2014), Malik et al. (2015) and Chand et al. (2015) (as cited in Rengarajan et al. 2016) in addition to the studies reviewed as dicussed in Chapter 2, tourism carrying capacity assessment is suggested as an appropriate tool in management and planning of sustainable tourism. Based on the results of CCA in each site, the threshold levels above which there may be physical, economic, socio-cultural and environmental destruction are evaluated; such that the proper and regular planning and monitoring of tourism development can be provided for the long-term sustainability of the natural resources. In case of beaches, there are many natural and anthropogenic factors that should be considered when implementing strategies for their long-term sustainability. In terms of utilization, CCA is an important tool to determine the saturation levels in order to avoid deterioration of these valuable tourist resources and maintain the enjoyment levels of beach users. So, in this study, carrying capacity analysis is conducted to ensure sustainable use of beaches in Kuşadası as Davutlar, Kadınlar, Güzelçamlı, Pamucak and natural beaches of Dilek National Park as Karasu, Kavaklıburun, Aydınlık and İçmeler. A summary of the RCCs of the beaches corrected by DSAS-WLR correction factors for present day and possible future RCCs of beaches as a result of SLR and accompanying erosion is presented in Table 5.11.

Table 5.11 Current RCCs of beaches in Kuşadası and RCCs in the next 100 years

Beach	*Present day RCC* (*Cf*$_{erosion\text{-}DSAS}$)	*RCC 2000-2025* (*Bruun-* DOC$_{Hallermeier}$*)*	*RCC 2000-2050* (*Bruun-* DOC$_{Hallermeier}$*)*	*RCC 2000-2075* (*Bruun-* DOC$_{Hallermeier}$*)*	*RCC 2000-2100* (*Bruun-* DOC$_{Hallermeier}$*)*
Karasu	322	*Bruun cannot be applied*	*Bruun cannot be applied*	*Bruun cannot be applied*	*Bruun cannot be applied*
Kavaklıburun	345	〃	〃	〃	〃
Aydınlık	511	〃	〃	〃	〃
İçmeler	195	〃	〃	〃	〃
Güzelçamlı	7879	7849	7749	7597	7480
Davutlar	24322	22173	19271	14920	11534
Kadınlar	997	58	0	0	0
Pamucak	8567	7404	5959	3790	2103

At this stage, the effect of the erosion (or accumulation) factor on beach carrying capacities is particularly noteworthy which directly affects the physical and therefore corrected real capacities of beaches especially for Kadınlar beach. The area of the available beach space for recreational use, which is the most important parameter in the calculation of carrying capacity, is a dynamic and time dependent parameter; so, in erosion prone coastal areas, usable beach areas will be much smaller in coming years and even disappear like Kadınlar and some parts of Davutlar and Pamucak in the next 100 years with this sea level rise and resulting erosion trends. The impact of sea level rise on Güzelçamlı is quite low. The results of RCCs after nearly 30 years (2000-2050) will decrease to half of the current RCCs for Davutlar and Pamucak. There are and will be other factors affecting the carrying capacities of these beaches that are not evaluated in this study; yet, considering the shoreline evolution impacts on RCCs it can be said that urgent and strict implementation of coastal zone management regulations is required for Kadınlar beach. Beach nourishment with coarser sediments as gravel can be suggested in response to shoreline evolution or make it more stable at least. Beach nourishment is also an effective way in conservation of ecology and coastal species. Also, removal of existing structures which support and/or accelarate the coastal erosion might be another solution if possible.

CHAPTER 6

CONCLUSION

In this study, carrying capacity analysis is conducted to ensure sustainable use of beaches in Kuşadası as Davutlar, Kadınlar, Güzelçamlı, Pamucak and natural beaches of Dilek National Park as Karasu, Kavaklıburun, Aydınlık and İçmeler. By considering the usable areas of the beaches and the climatic and geomorphological characteristics of the region that have changed over the years, the physical carrying capacity and real carrying capacity for each beach have been calculated theoretically by adapting Cifuentes (1992) method. Factors restricting the use of the beaches changes carrying capacity results by more than half of the physical carrying capacities. According to the comparisons between PCC (Table 5.2) and RCC (Table 5.6), the importance of site-specific correction factors can be observed. Among the climatic characteristics of Kuşadası region, excessive sunshine has the greatest impact on decreasing the carrying capacities.

In this study, in addition to defining the current characteristics and carrying capacities of beaches, the impact of climate change such as sea level rise, shoreline evolution and air temperature rise on the carrying capacity has been examined. Bruun rule were applied to the beaches of sandy type (Davtlar, Güzelçamlı, Pamucak and Kadınlar) to calculate shoreline retreats in coming 100 years based on sea level rise trends of East Mediterranean (Vousdoukas et al. 2017) and Menteş coast (Alper 2009). The area of the available beach space for recreational use, which is the most important parameter in the calculation of carrying capacity, is a dynamic and time dependent parameter; so, in erosion prone coastal areas, usable beach areas will be much smaller in coming years. They might even disappear like in Kadınlar (Table 4.11) and some parts of Davutlar and Pamucak (Table 4.14) in the next 100 years based on the resulting erosion trends calculated in this study. On the other hand, the impact of sea level rise on Güzelçamlı is quite low which indicates not all the beaches in close proximity with each other would be affected similarly because of sea level rise. These results highlight the need for BCC analysis to be done for each beach not for a group of beaches of an area. In addition to the SLR projections, temperature rise scenarios are also applied as correction factor to measure the future RCCs of beaches. With increasing temperatures in less than 100 years, the real carrying capacities of beaches will drop nearly to the half of the present RCCs. So, if these beaches are still used by visitors, these visitors will be naturally forced to adapt their comfort perceptions and considerations regarding excessive heat and sunshine.

Sustainable development in tourism industry is important to maintain the conservation and protection of sensitive and fragile natural and touristic destinations in order to enhance tourist flows and revenues as well as protection of natural beauty of the area. So, beach carrying capacity assessment is one of effective ways for the management of tourism development on a more sustainable basis. Exceeding the limit that the area can physically carry and/or non-homogenous distribution of beach users may disrupt the physical and ecological balance in these areas as well as the natural impacts such as sea level and temperature rise. So, based on the results of beach carrying capacity assessment for beaches of Kuşadası including the impacts of climate change, which is a first of its kind for Turkish beaches, Coastal Zone Management Planning strategies may be developed in order to preserve coastal areas evaluated in this study such as;

- Structural and/or management solutions can be developed in order to preserve the Kadınlar beach area which is the first beach (among the beaches evaluated in this study) to be affected by sea level rise in coming years. Beach nourishment may be an effective solution to slow down the beach retreat and deterioration of ecological balance.
- Homogeneous distribution of beach users may be ensured in especially beaches of Davutlar and Pamucak by improving for example transportation and parking availability to the sections of beaches far away from city center

especially to D-1 section of Davutlar near the Güzelçamlı beach (which is wider in terms of beach width and much less crowded by public).

- Number of beach users entering the beaches can be regulated by letting in the maximum number that beaches can physically and environmentally tolerate (limited ticket sales) in case of beaches of Dilek National Park with restricted use.

Physical carrying capacities of beaches were calculated only considering the available beach area provided from Google Earth satellite imagery in this study. Whereas, in reality there are more available areas (under trees and spots that were not detected in satellite imagery) or recreational use in some of the beaches, especially the ones in Dilek National Park). For this purpose, aerial photography of the study site will lead us to more accurate results for both PCC and RCC. Also, data from the available cameras shooting the sites or/and entrance tickets (Dilek National Parks) could be collected for comparison purposes.

Moreover, the RCC results of this study is based on physical conditions that limit the use of beaches. Therefore, in order to obtain more accurate results, Effective Carrying Capacity of each site should be taken into account. In some beaches, factors like accessibility, parking space, local accommodation, infrastructure and available facilities, cleanliness, security level, water, sand, environmental and ecological quality may also have correcting or limiting impacts on the beach use.

Additionally, the perception of beach users is important on deciding whether they are able to use the beaches with the future conditions which will possibly get worse in coming years (as temperature rises, sea level rises, shoreline evolution decreases the available beach area and etc.) or not. Hence, for further studies, it is recommended that the effects of social and recreational experience parameters on beach usage and consequently on the carrying capacity of visitors should be taken into consideration in future studies. The density of visitors per day and per hour, the frequency of coming across with other groups, the size of the groups, the proportion of recreation areas on the beaches and similar parameters should be analyzed for this purpose. These analyzes should be obtained through surveys aimed at measuring the crowd perception of visitors. The results of this analysis should support the assessment of management plans and strategies necessary for sustainable use of these areas, taking existing community goals and future perceptions into account.

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APPENDICES

A. Climatic Data Analysis

Table A.1 Duration of specified temperature in hours for 1979-2018 years

Months	*25-26° C*	*26-27° C*	*27-28° C*	*28-29° C*	*29-30° C*	*30-31° C*	*31-32° C*	*32-33° C*	*33-34° C*	*34-35° C*	*35-36°*	*36-37° C*	*37-38° C*	*38-39*
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	4	0	0	0	0	0	0	0	0	0	0	0	0	0
April	129	43	14	6	5	0	0	0	0	0	0	0	0	0
May	1085	762	522	355	192	71	25	7	3	0	0	0	0	0
June	2185	2130	1814	1610	1237	985	720	504	300	184	61	17	1	0
July	2771	2515	2207	2119	2100	1995	1799	1571	1106	622	299	153	35	13
August	3072	2562	2356	2219	2078	1902	1826	1424	1178	724	366	124	46	0
September	2139	2132	1667	1429	1116	808	397	258	159	21	0	2	2	0
October	959	554	347	204	83	44	8	3	0	0	0	0	0	0
November	27	21	0	0	0	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total hours per 40 years	12371	10719	8927	7942	6811	5805	4775	3767	2746	1551	726	296	84	13

Table A.2 Average values of precipitation for Kuşadası (1979-2018)

Months	*Average Number of Days with Precipitation, days/year*	*Average Rainfall Intensity, m/hour.year*	*Average Rainfall Duration, hour/year*	*Average Maximum Rainfall Intensity, m/hour.year*	*Average Minimum Rainfall Intensity, m/hour.year*
January	21	1.91E-04	339	1.36E-03	0
February	20	1.61E-04	297	1.12E-03	0
March	21	1.19E-04	257	1.09E-03	0
April	18	6.98E-05	196	6.37E-04	0
May	15	3.57E-05	133	4.68E-04	0
June	8	8.83E-06	55	1.16E-04	0
July	3	1.37E-06	15	3.09E-05	0
August	4	1.74E-06	18	3.69E-05	0
September	8	2.85E-05	64	5.14E-04	0
October	14	8.22E-05	151	1.05E-03	0
November	18	1.67E-04	267	1.46E-03	0
December	23	2.06E-04	359	1.33E-03	0
Total	172	-	2151	-	-

B. Shoreline Evolution Statistics

Net Shoreline Movement (NSM)

According to the average shoreline movements measured and presented in Table B.2, it is clear that erosion was dominant for Güzelçamlı and accretion was dominant for Davutlar and Pamucak beaches in the last 15 years. The net positions of shorelines of other beaches is assumed as stable in the last 15 years considering the net shoreline movement determined by DSAS is much smaller than the spatial resolution of these images (lower than 2 meters for 2004-2010 years) (Satellite Imaging Corporation, 2017).

Table B.1 Net Shoreline Movement Results

Beach	*Average distance, m*	*Percentage of all transects that have a negative distance*	*Maximum negative distance*	*Average of all negative distances*	*Percentage of all transects that have a positive distance*	*Maximum positive distance*	*Average of all positive distances*
Karasu	1.84	16.67	-4.62	-2.15	83.33	4.43	2.64
Kalamaki	-0.39	57.69	-3.93	-1.45	42.31	3.2	1.05
Aydınlık	-1.53	70	-7.22	-2.74	30	3.21	1.28
İçmeler	-0.94	64.29	-3.92	-2.1	35.71	2.01	1.15
Güzelçamlı	-2.2	71.68	-14.1	-4.01	28.32	17.62	2.38
Davutlar	5.47	18.62	-9.67	-2.11	81.38	48.33	7.2
Kadınlar	-0.56	48.48	-7.3	-2.85	51.52	4.05	1.59
Pamucak	4.55	43.89	-65.64	-14.82	56.11	56.49	19.7

End Point Rate (EPR)

Similar to the results of NSM, beaches with mostly erosional transects are determined as Kavaklıburun, Aydınlık, İçmeler, Güzelçamlı and Kadınlar and beaches with mostly accretional transects are Karasu, Davutlar and Pamucak presented in Table B.2. Although there are changes in the shoreline rates, most of the calculated trends are very small and less than 0.5 m/year; therefore, considering the lower resolution of satellite imagery most of these beaches can be considered as stable.

Table B.2 End Point Rates Results

Beach	*Average rate with reduced uncertainty*	*Percent of all transects that are erosional*	*Percent of all transects that have statistically significant erosion*	*Maximum value erosion*	*Average of all erosiona*	*Percent of all transects that are accretional*	*Percent of all transects that have*	*Maximum value accretion*	*Average of all accretio*
Karasu	0.32 +/- 0.38	43.89	26.7	-4.62	-1.05	56.11	45.7	3.98	1.39
Kalamaki	-0.04 +/- 0.25	48.48	18.18	-0.52	-0.2	51.52	6.06	0.29	0.12
Aydınlık	0.38 +/- 0.27	18.62	1.33	-0.68	-0.15	81.38	50.27	3.37	0.5
İçmeler	-0.15 +/- 0.52	71.68	11.56	-0.98	-0.28	28.32	1.73	1.23	0.17
Güzelçamlı	-0.07 +/- 0.36	64.29	0	-0.28	-0.15	35.71	0	0.14	0.08
Davutlar	-0.11 +/- 0.28	70	12.5	-0.51	0.19	30	0	0.23	0.09
Kadınlar	-0.05 +/- 0.47	57.69	1.92	-0.54	-0.2	42.31	0	0.44	0.14
Pamucak	0.13 +/- 0.28	16.67	4.17	-0.33	-0.15	83.33	12.5	0.32	0.19

Linear Regression Rate (LRR)

LRR does not include any possible uncertainties of positions of shorelines; so, most of the beaches except for Pamucak can be considered as stable. According to the LRR results presented in Table B.3, Pamucak shows the most significant trend among the beaches with 85% of all transects being accretional; whereas, Karasu, Kavaklıburun and Kadınlar shows balanced evolution for the last 15 years.

Table B.3 Linear Regression Rates Results

Beach	*Average rate with reduced uncertainty*	*Percent of all transects that are erosional*	*Percent of all transects that have statistically significant erosion*	*Maximum value erosion*	*Average of all erosional rates*	*Percent of all transects that are*	*Percent of all transects that have statistically significant*	*Maximum value accretion*	*Average of all accretional rates*
Karasu	0.03 +/- 0.17	37.5	8.33	-0.37	-0.22	62.5	16.67	0.31	0.18
Kalamaki	-0.03 +/- 0.2	55.77	0	-0.49	-0.18	44.23	0	0.29	0.16
Aydınlık	-0.17 +/- 0.14	70	42.5	-0.54	-0.28	30	0	0.17	0.1
İçmeler	0.37 +/- 0.24	0	0	-	-	100	21.43	0.44	0.37
Güzelçamlı	-0.25 +/- 0.12	83.24	36.42	-1.03	-0.33	16.76	2.31	0.95	0.12
Davutlar	0.28 +/- 0.19	29.52	7.45	-1.44	-0.17	70.48	31.38	2.63	0.47
Kadınlar	0.05 +/- 0.21	39.39	0	-0.08	-0.04	60.61	3.03	0.33	0.1
Pamucak	1.15 +/- 0.16	15.38	11.76	-3.41	-1.69	84.62	61.99	4.55	1.67

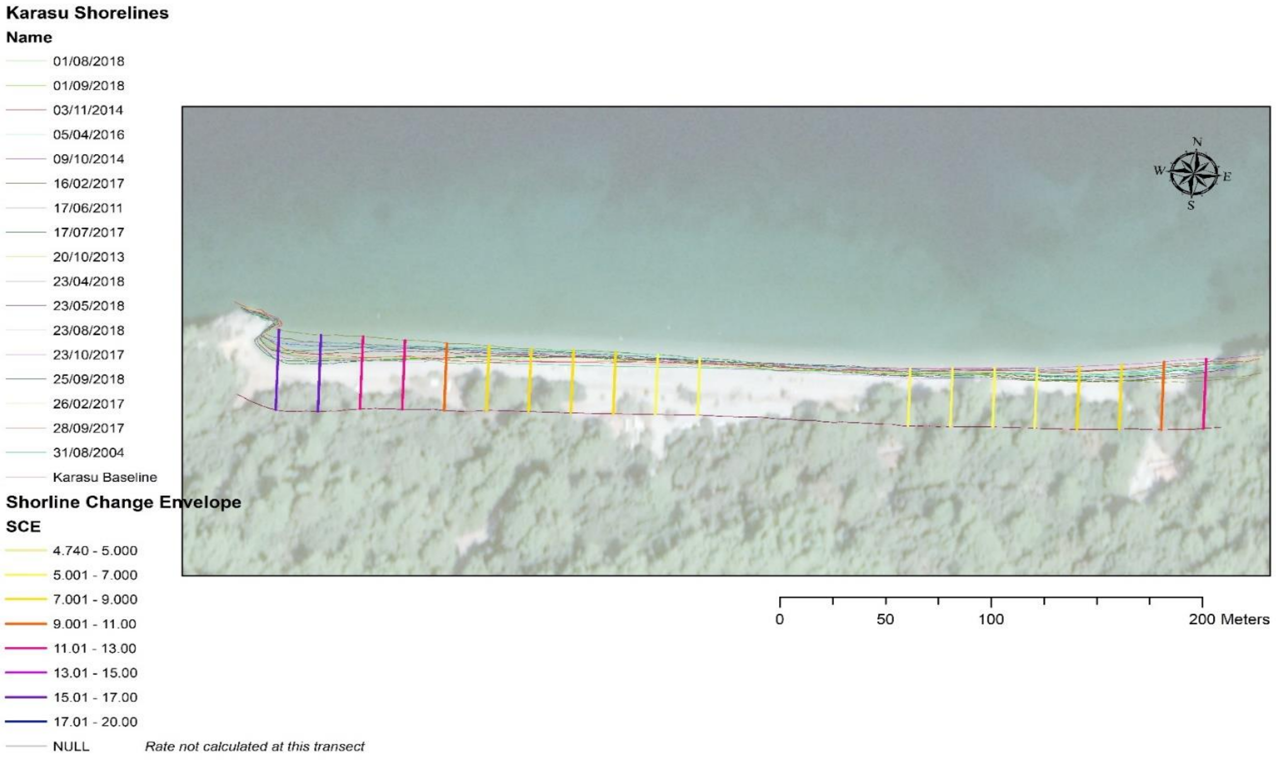

Figure B.1 Karasu DSAS-SCE Map (ArcMap)

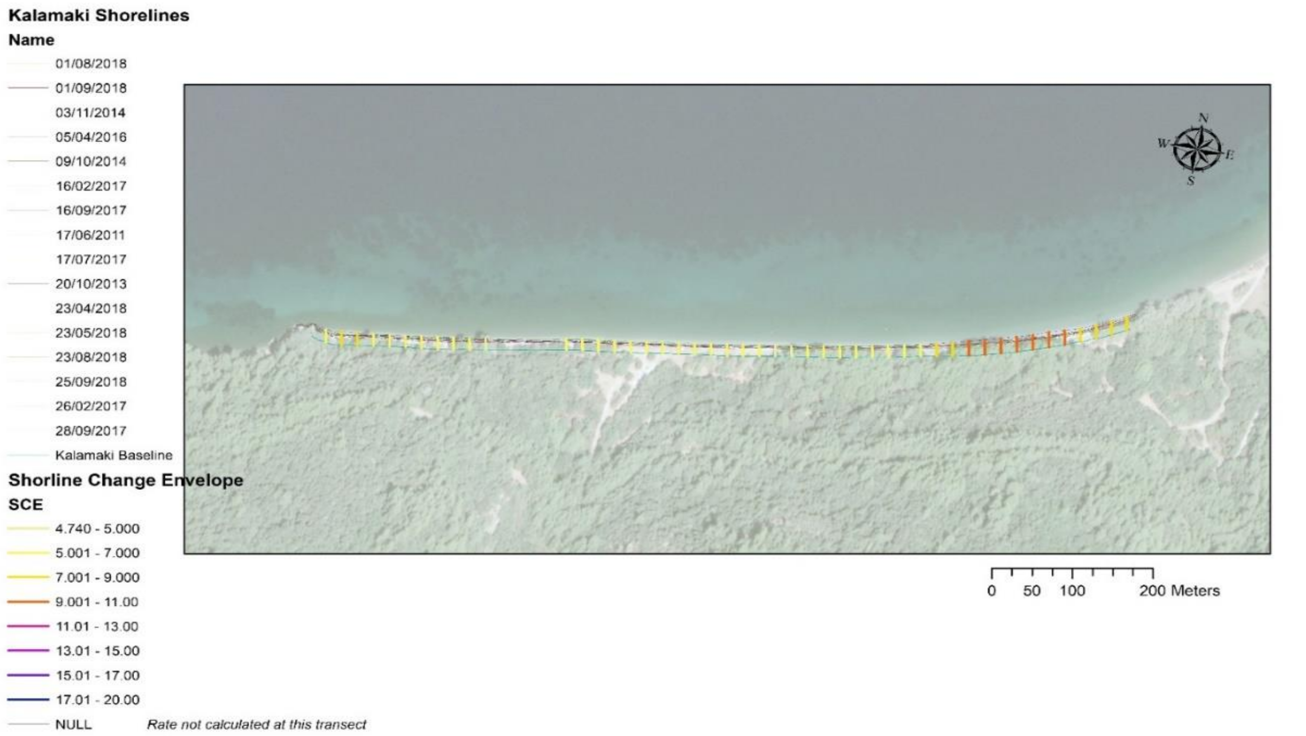

Figure B.2 Kavaklıburun (Kalamaki) DSAS-SCE Map (ArcMap)

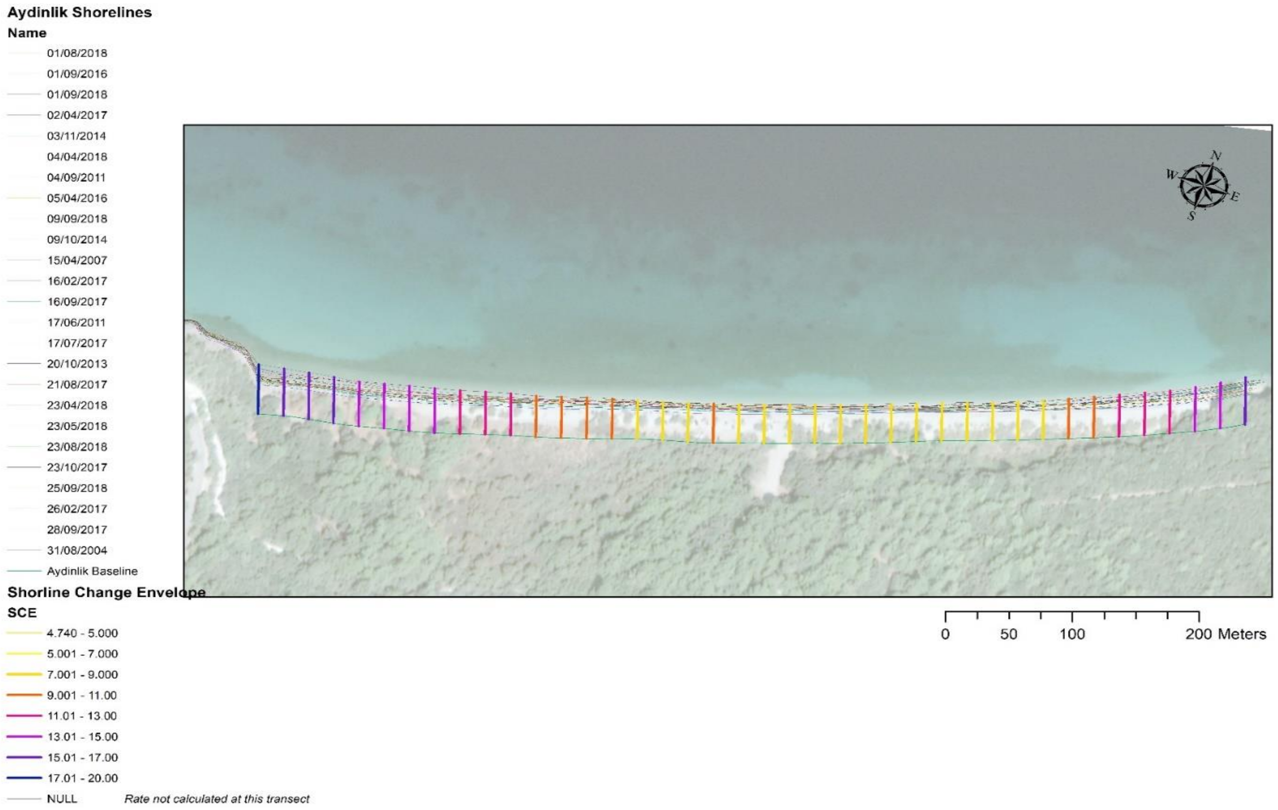

Figure B.3 Aydınlık DSAS-SCE Map (ArcMap)

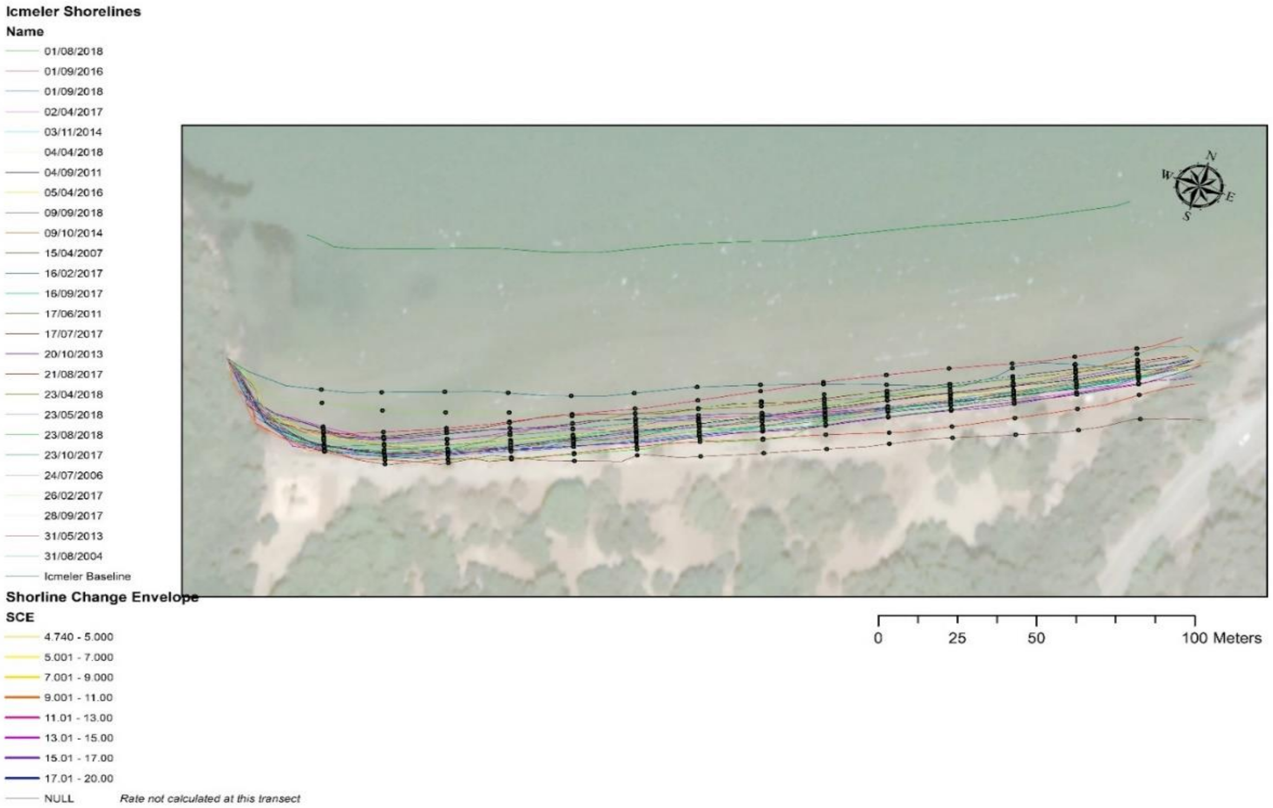

Figure B.4 İçmeler DSAS-SCE Map (ArcMap)

Figure B.5 Davutlar (Section D-1) DSAS-SCE Map (ArcMap)

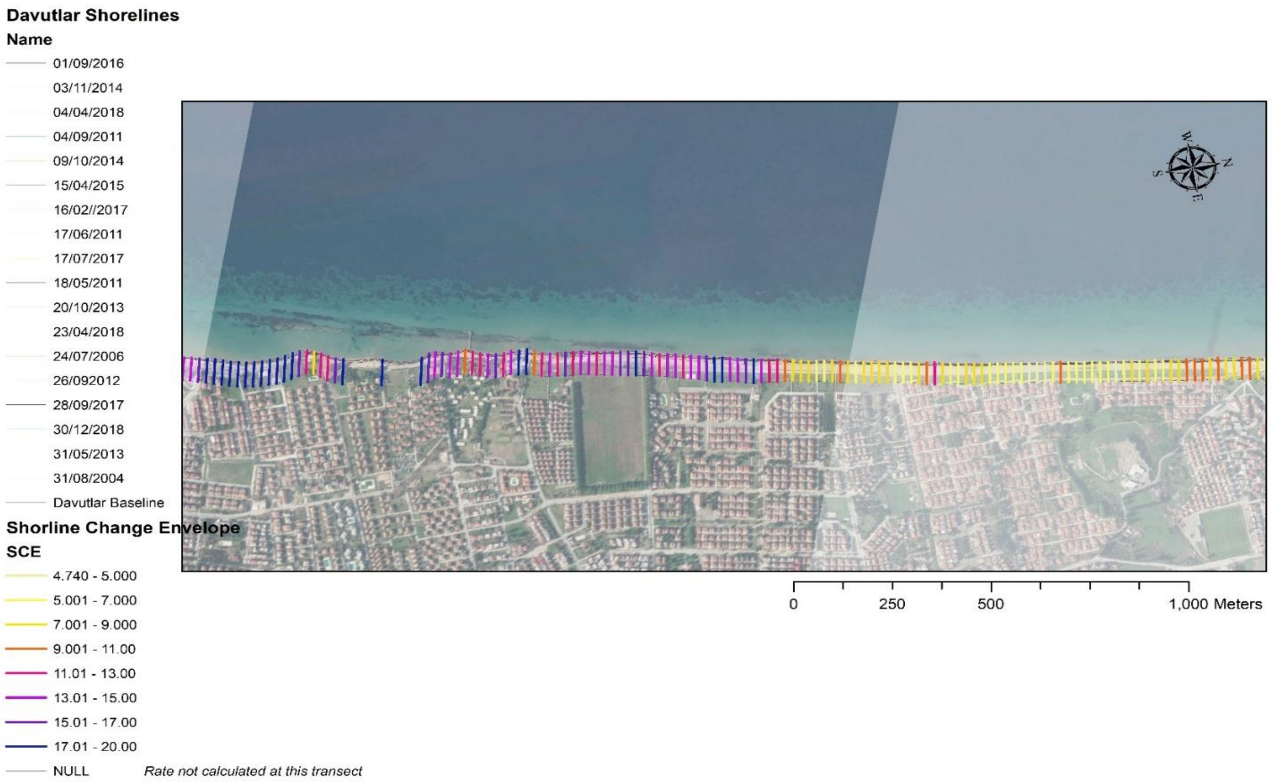

Figure B.6 Davutlar (Section D-2) DSAS-SCE Map (ArcMap)

Figure B.7 Davutlar (Section D-3) DSAS-SCE Map (ArcMap)

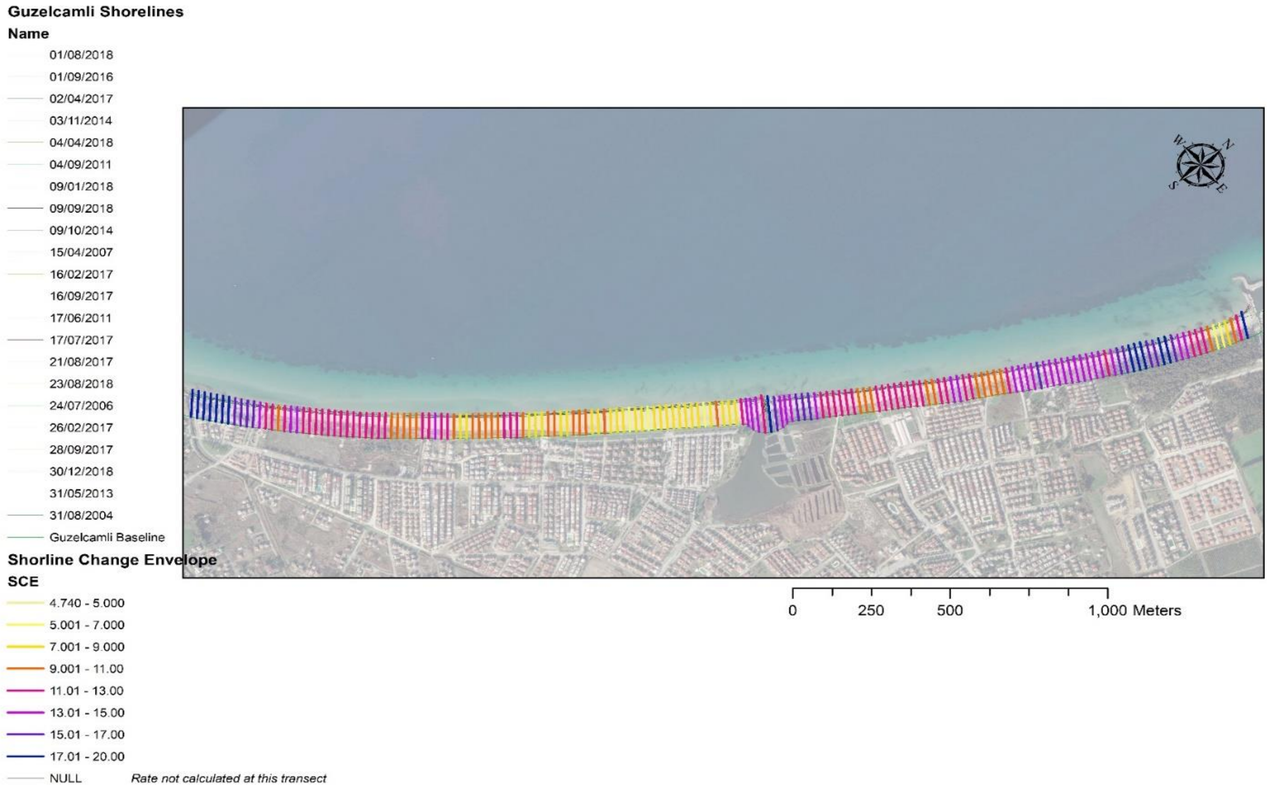

Figure B.8 Güzelçamlı DSAS-SCE Map (ArcMap)

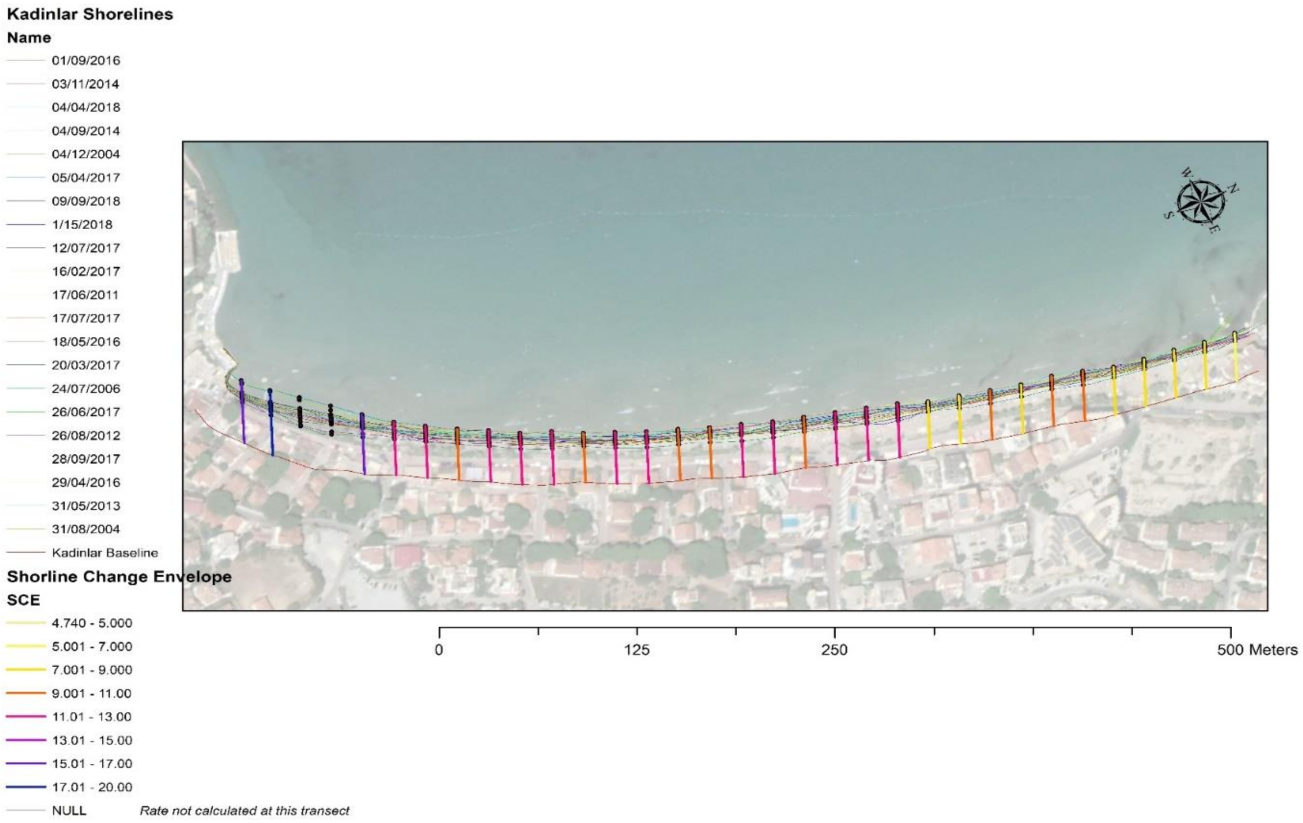

Figure B.9 Kadınlar DSAS-SCE Map (ArcMap)

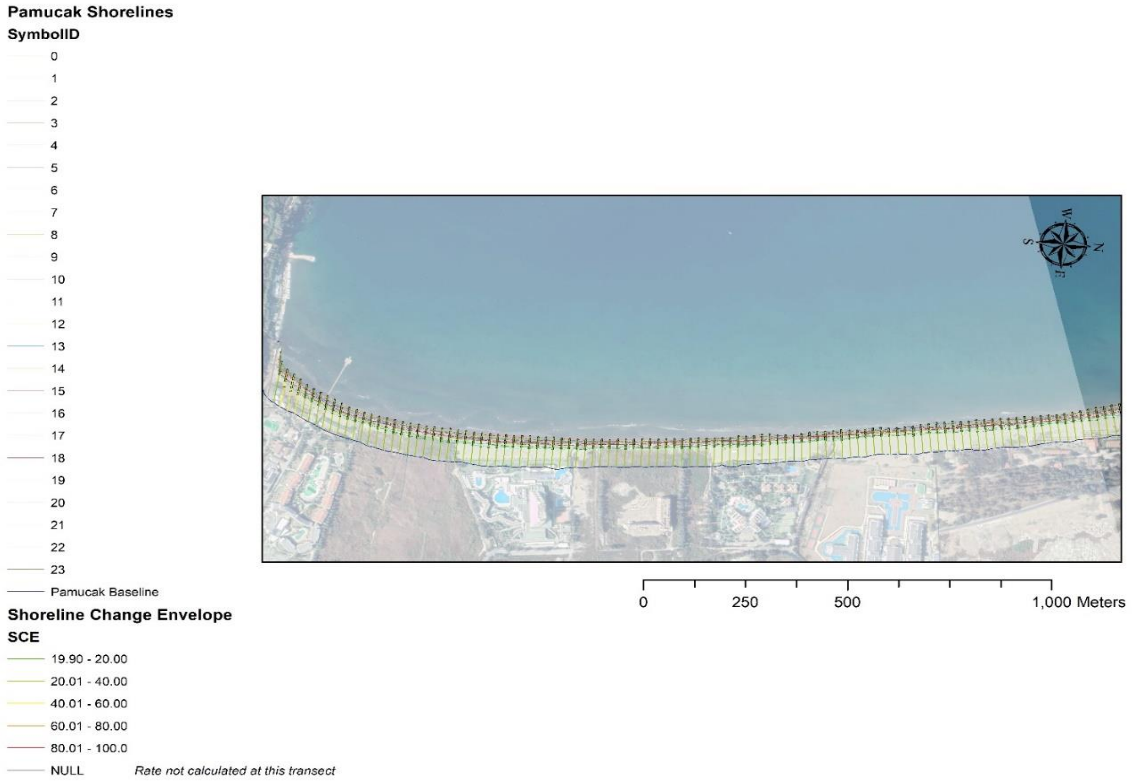

Figure B.10 Pamucak (Section P-1) DSAS-SCE Map (ArcMap)

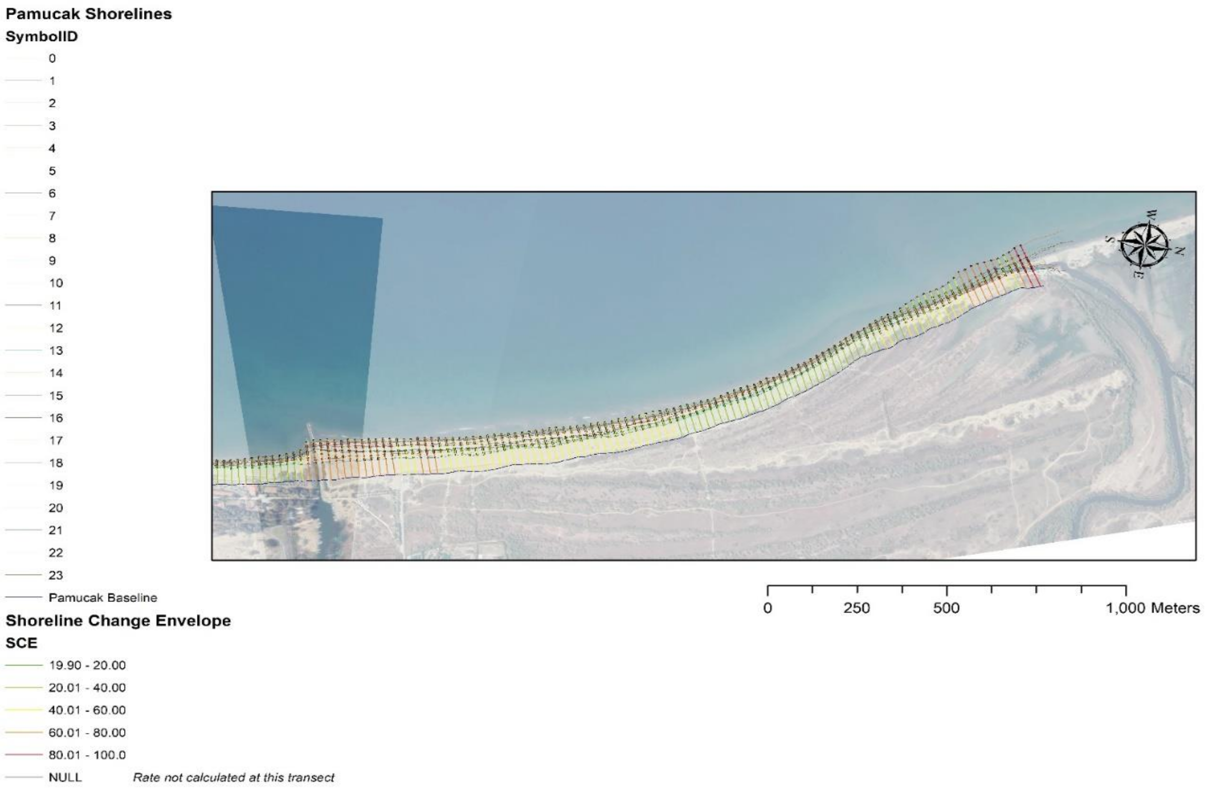

Figure B.11 Pamucak (Section P-2) DSAS-SCE Map (ArcMap)

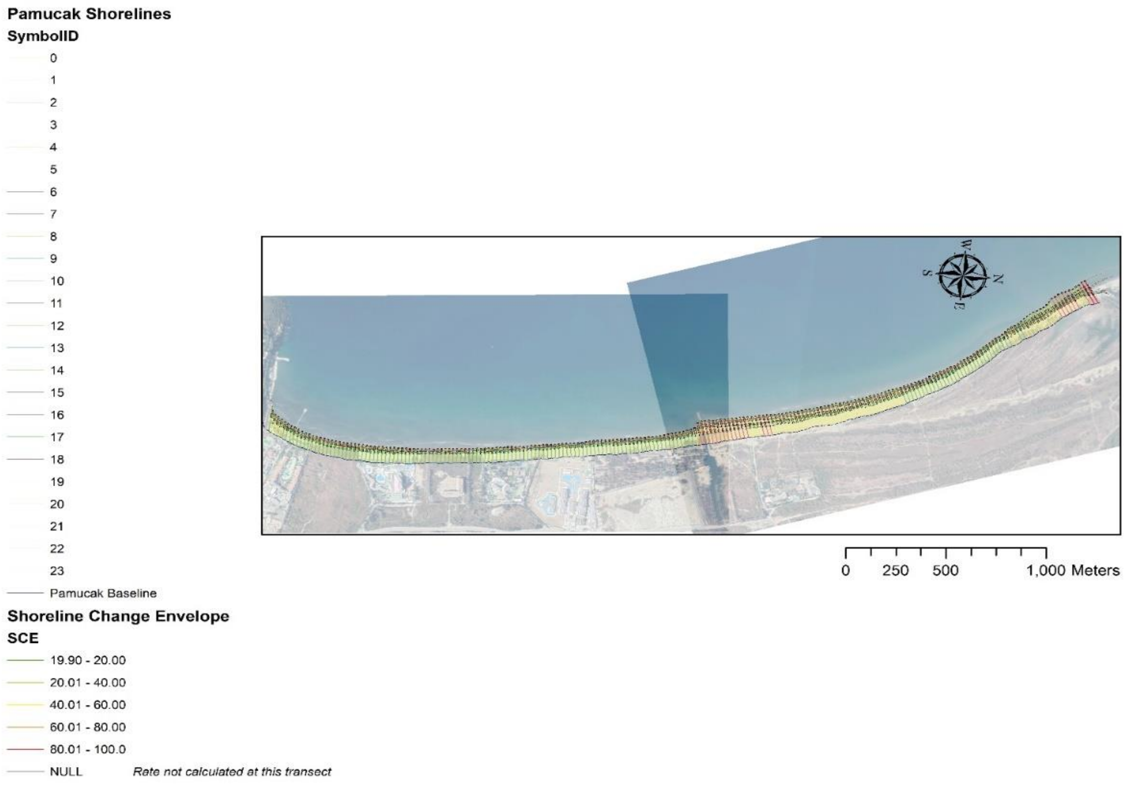

Figure B.12 Pamucak DSAS-SCE Map (ArcMap)

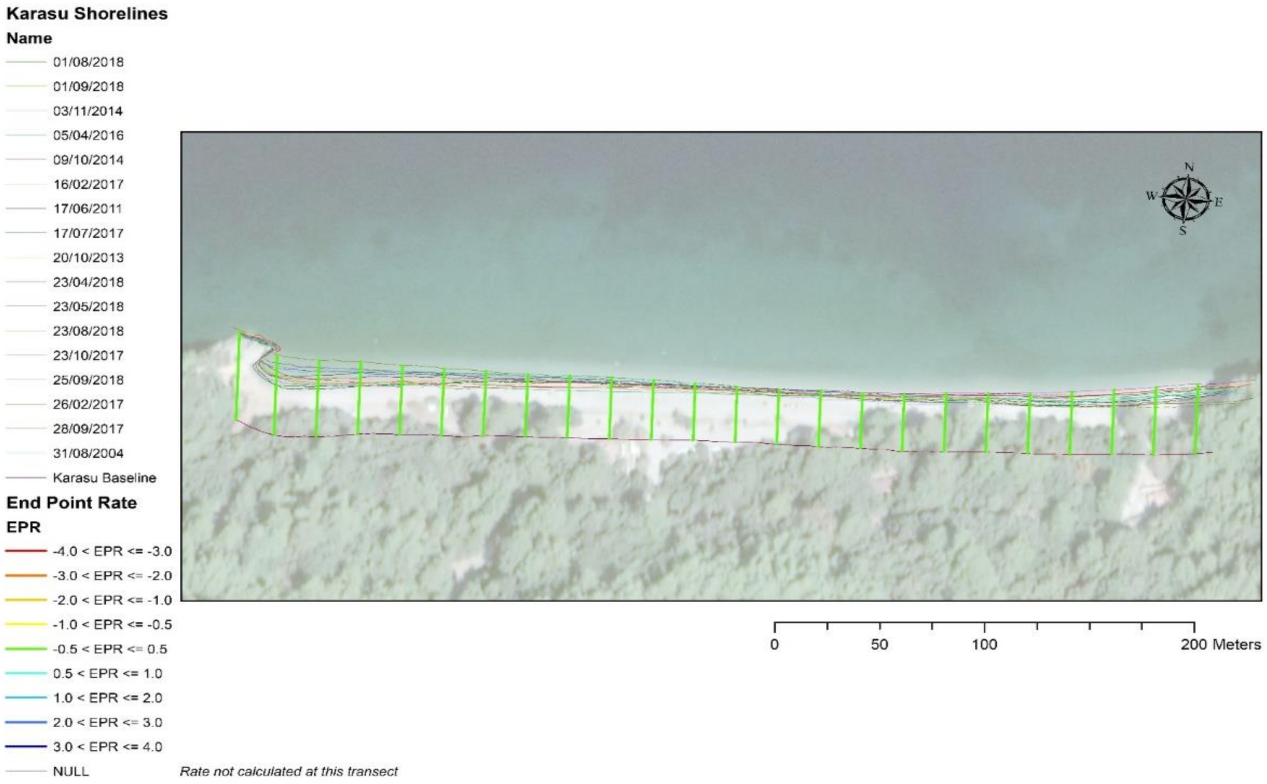

Figure B.13 Karasu DSAS-EPR Map (ArcMap)

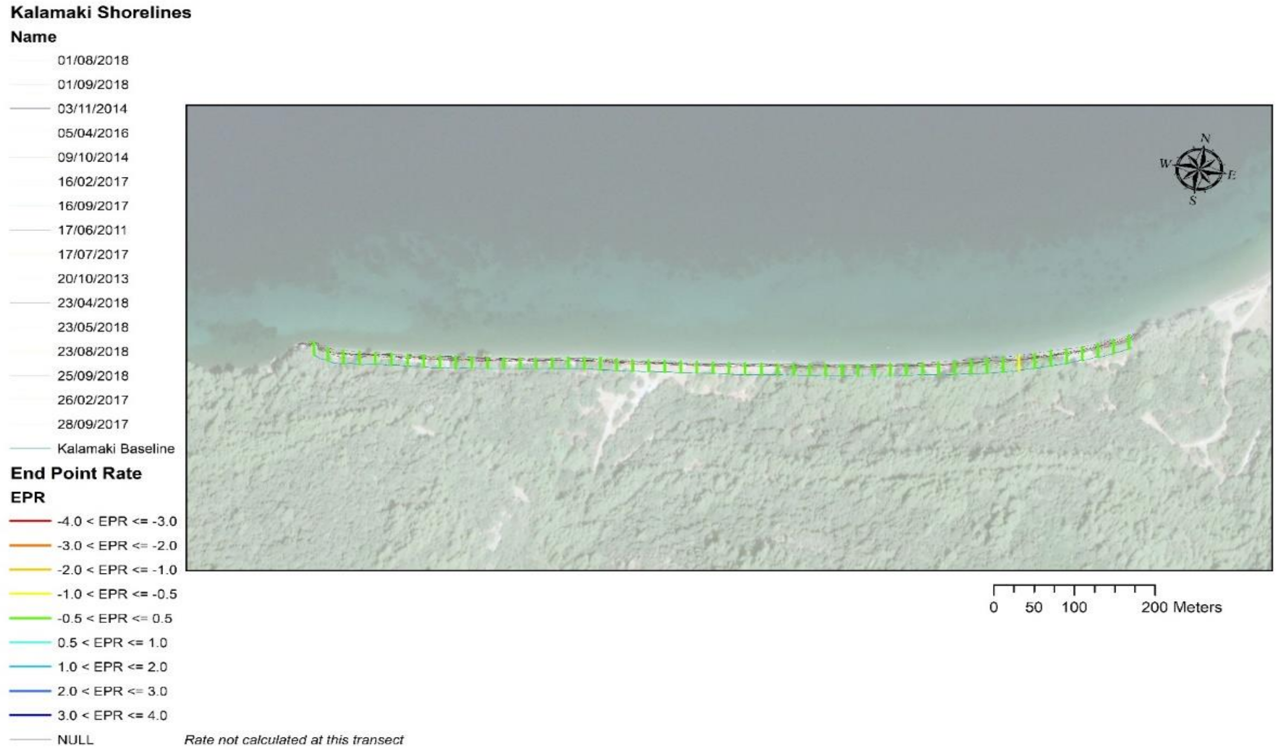

Figure B.14 Kavaklıburun (Kalamaki) DSAS-EPR Map (ArcMap)

Figure B.15 Aydınlık DSAS-EPR Map (ArcMap)

Figure B.16 İçmeler DSAS-EPR Map (ArcMap)

Figure B.17 Davutlar (Section D-1) DSAS-EPR Map (ArcMap)

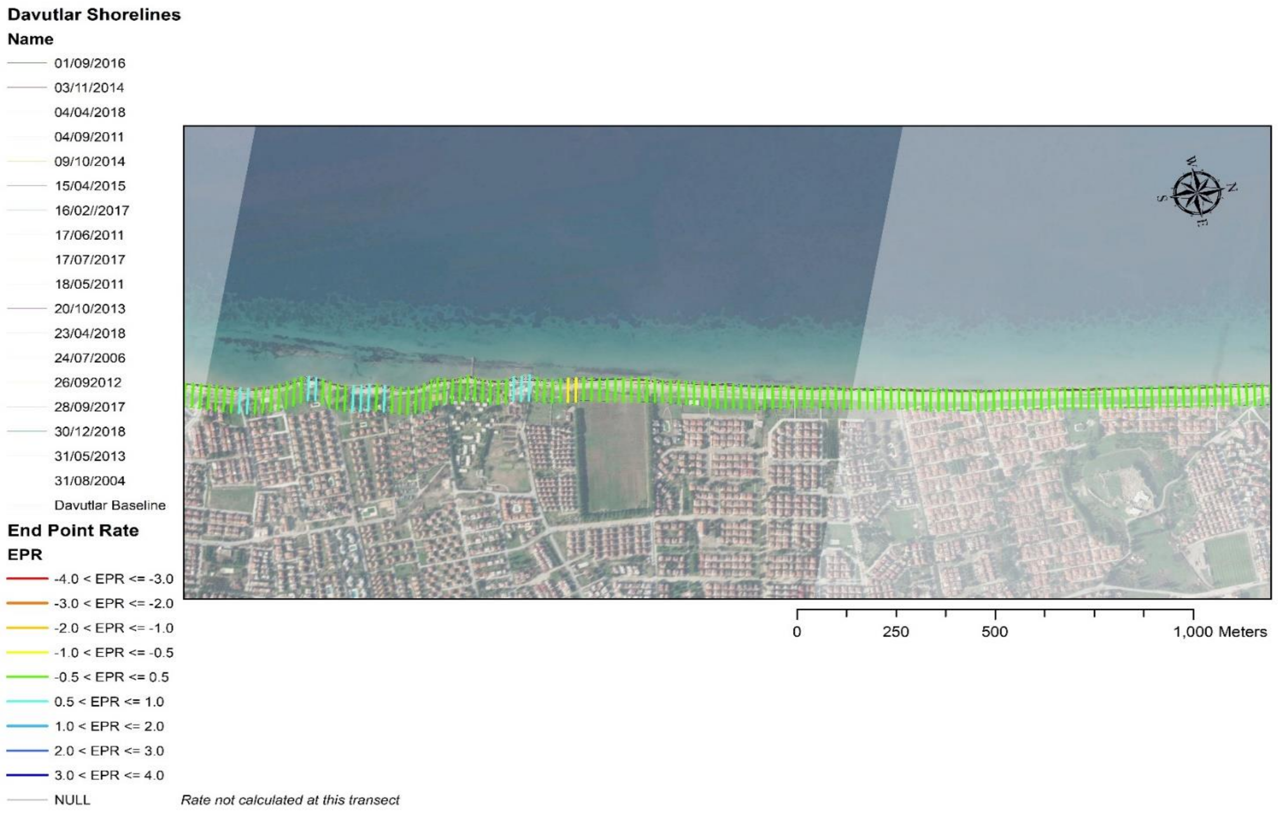

Figure B.18 Davutlar (Section D-2) DSAS-EPR Map (ArcMap)

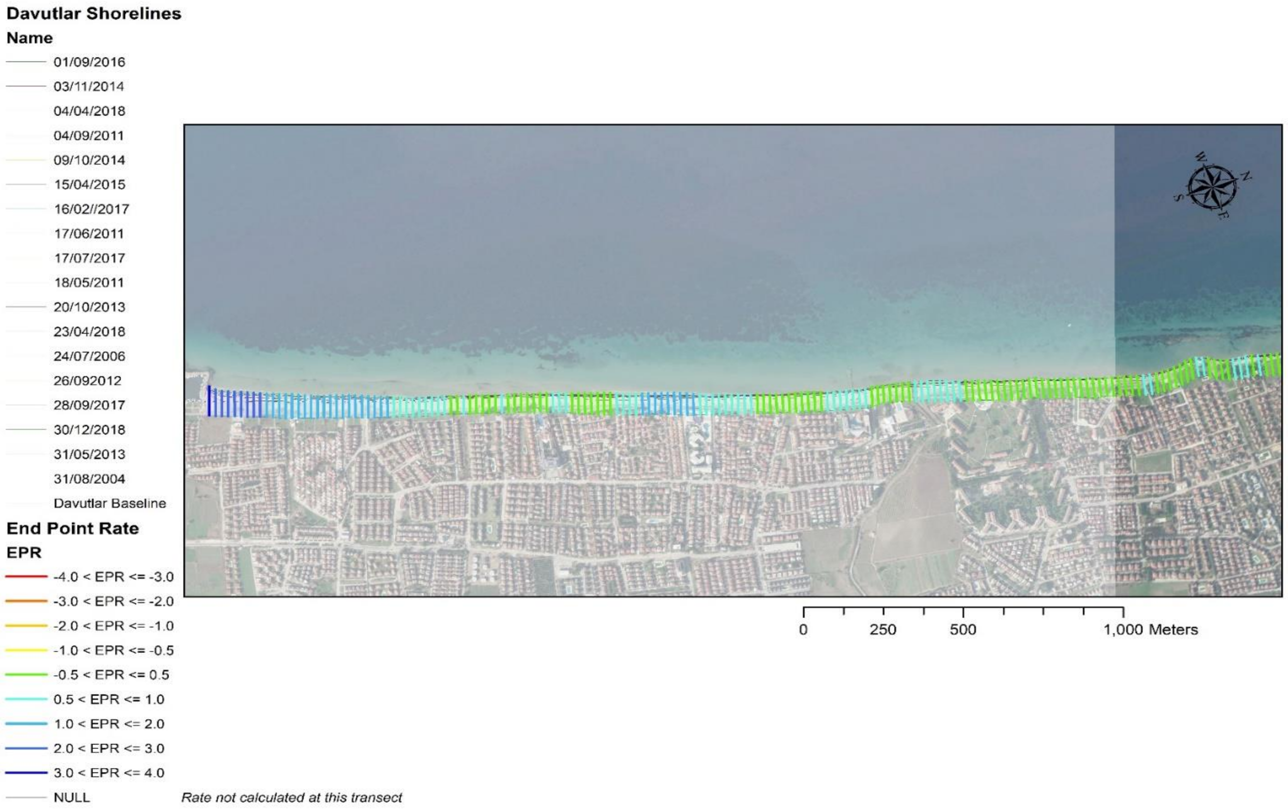

Figure B.19 Davutlar (Section D-3) DSAS-EPR Map (ArcMap)

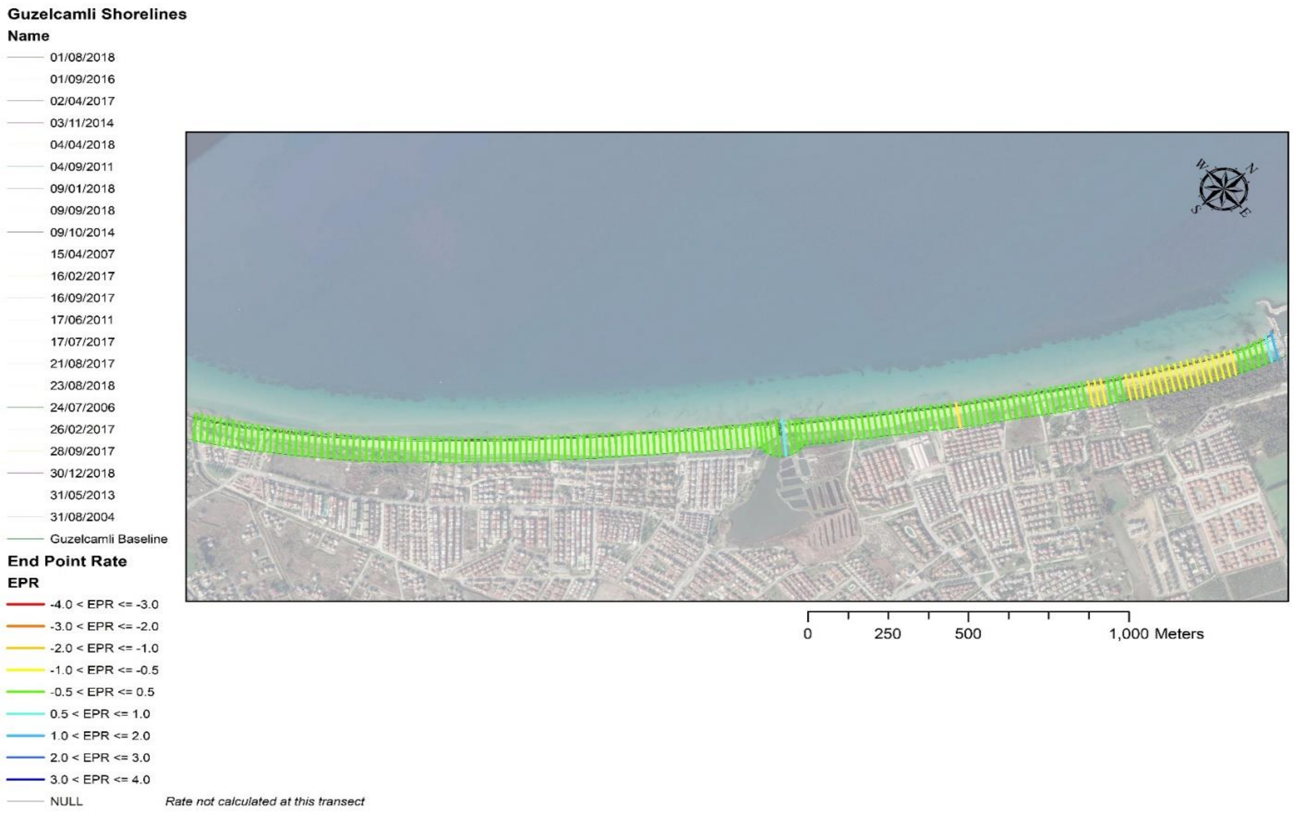

Figure B.20 Güzelçamlı DSAS-EPR Map (ArcMap)

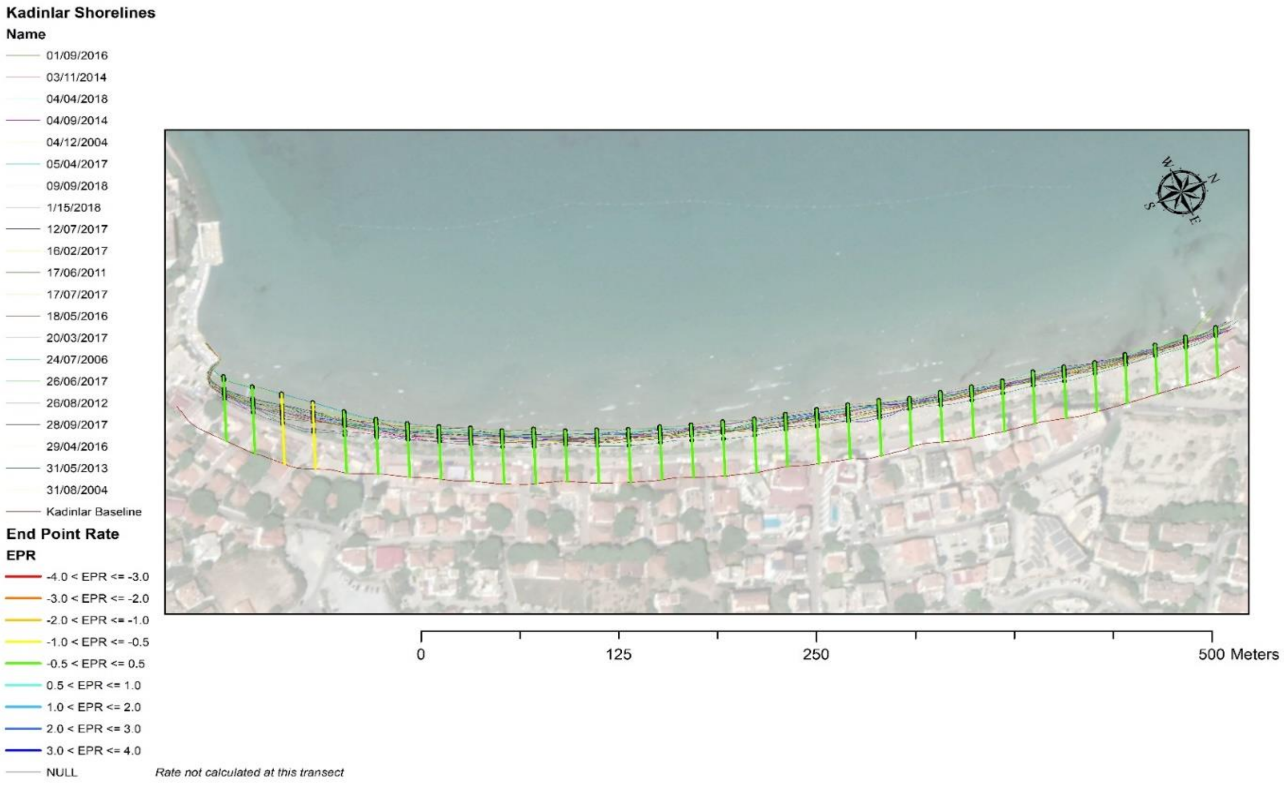

Figure B.21 Kadınlar DSAS-EPR Map (ArcMap)

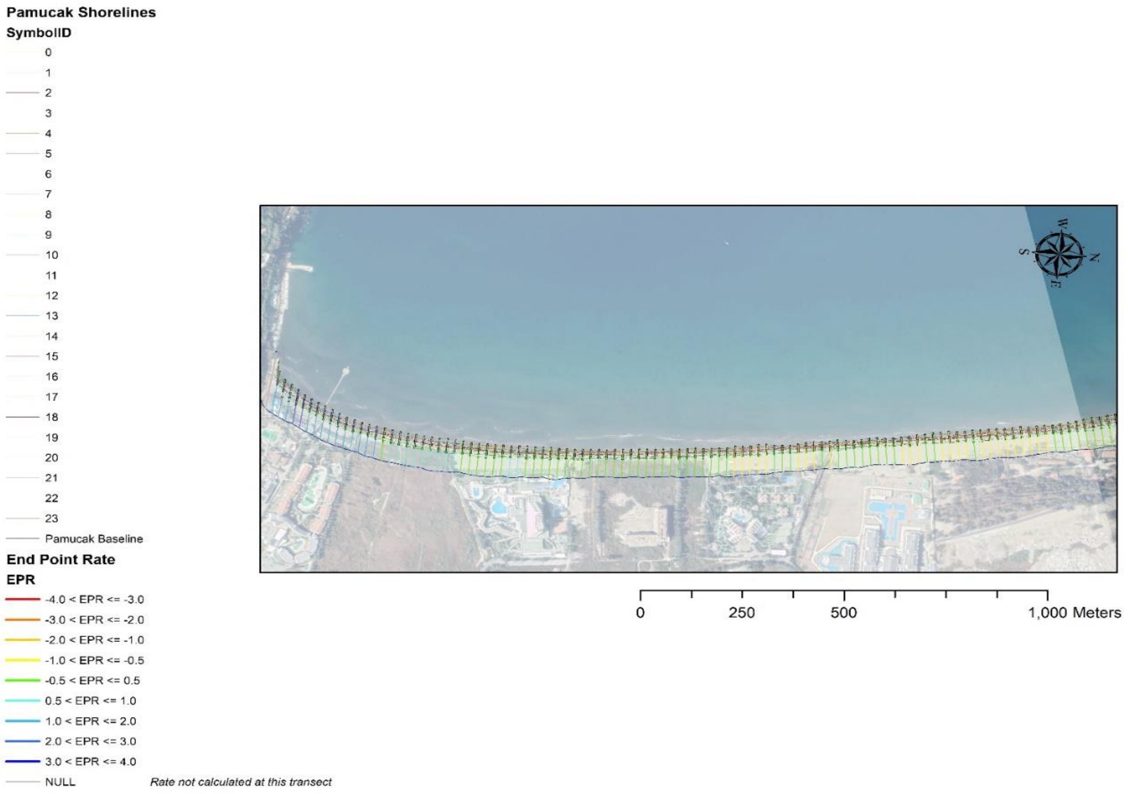

Figure B.22 Pamucak (Section P-1) DSAS-EPR Map (ArcMap)

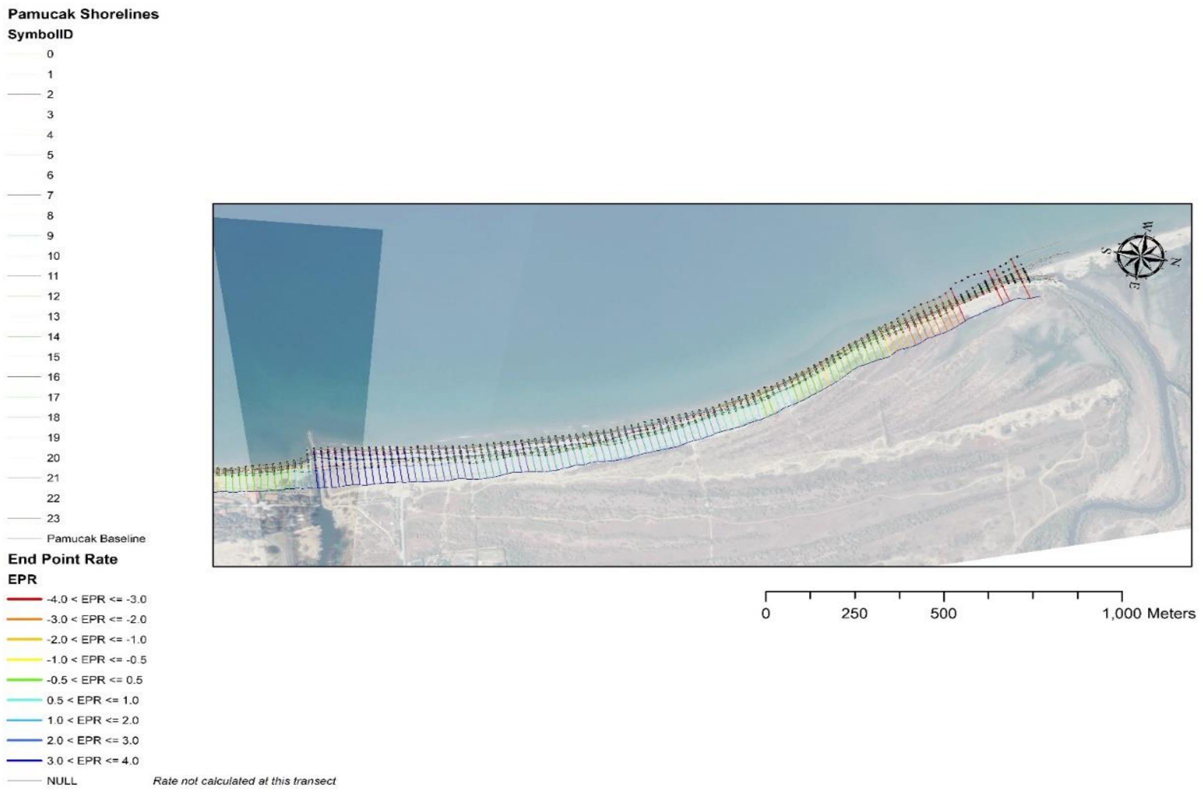

Figure B.23 Pamucak (Section P-2) DSAS-EPR Map (ArcMap)

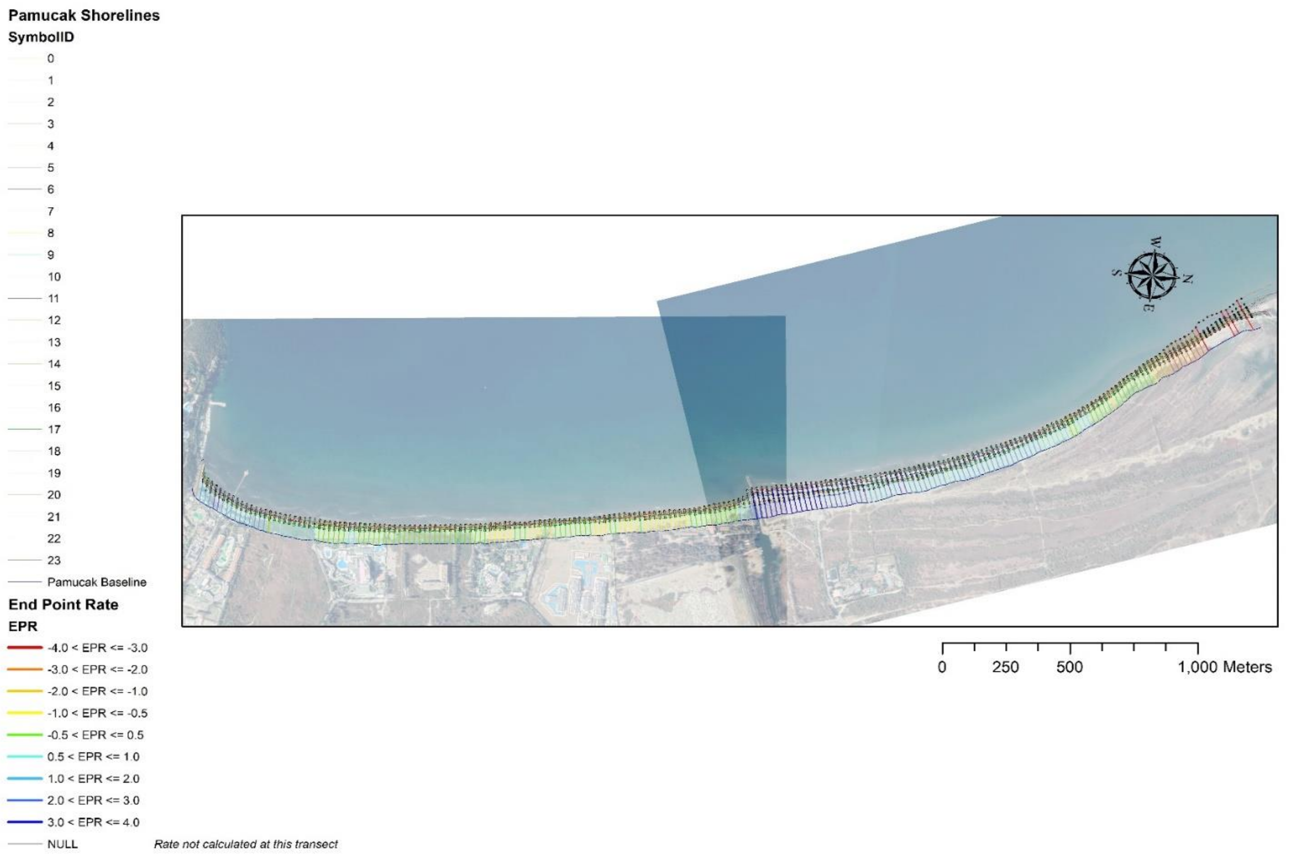

Figure B.24 Pamucak DSAS-EPR Map (ArcMap)

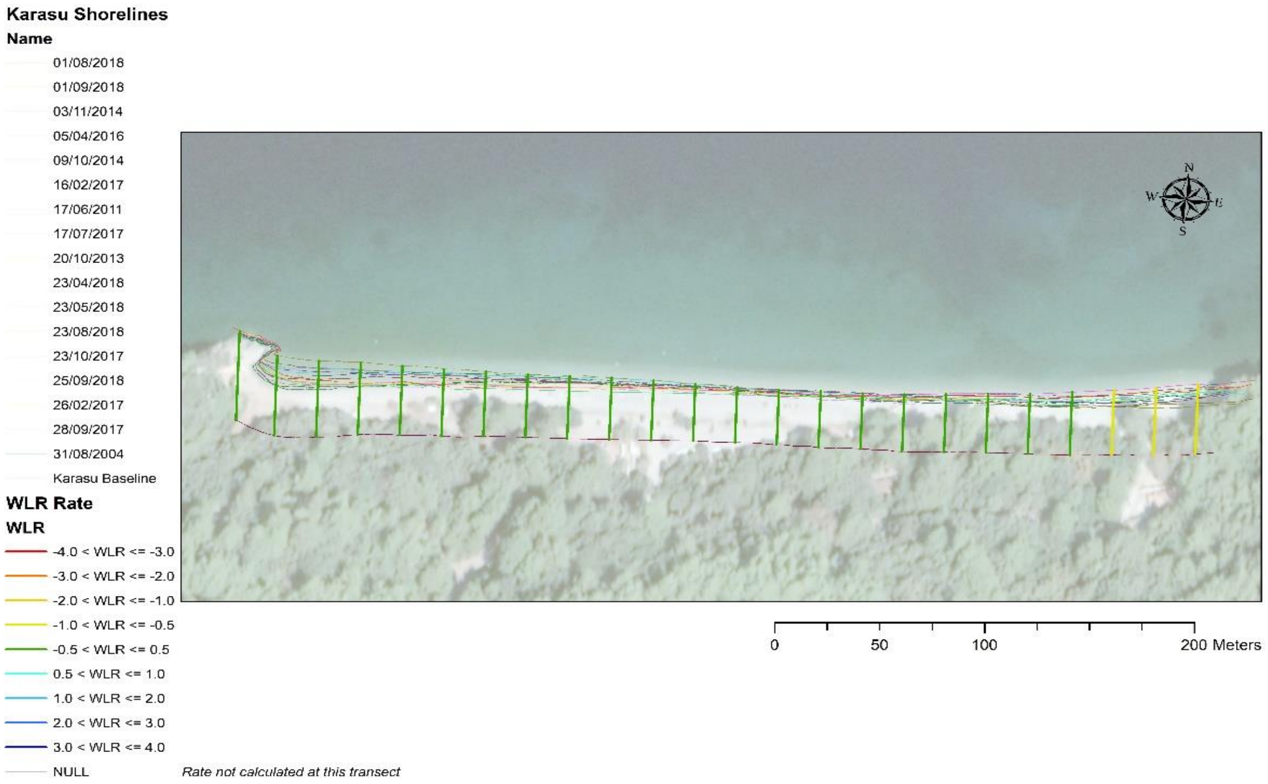

Figure B.25 Karasu DSAS-WLR Map (ArcMap)

Figure B.26 Kavaklıburun (Kalamaki) DSAS-WLR Map (ArcMap)

Figure B.27 Aydınlık DSAS-WLR Map (ArcMap)

Figure B.28 İçmeler DSAS-WLR Map (ArcMap)

Figure B.29 Davutlar (Section D-1) DSAS-WLR Map (ArcMap)

Figure B.30 Davutlar (Section D-2) DSAS-WLR Map (ArcMap)

Figure B.31 Davutlar (Section D-3) DSAS-WLR Map (ArcMap)

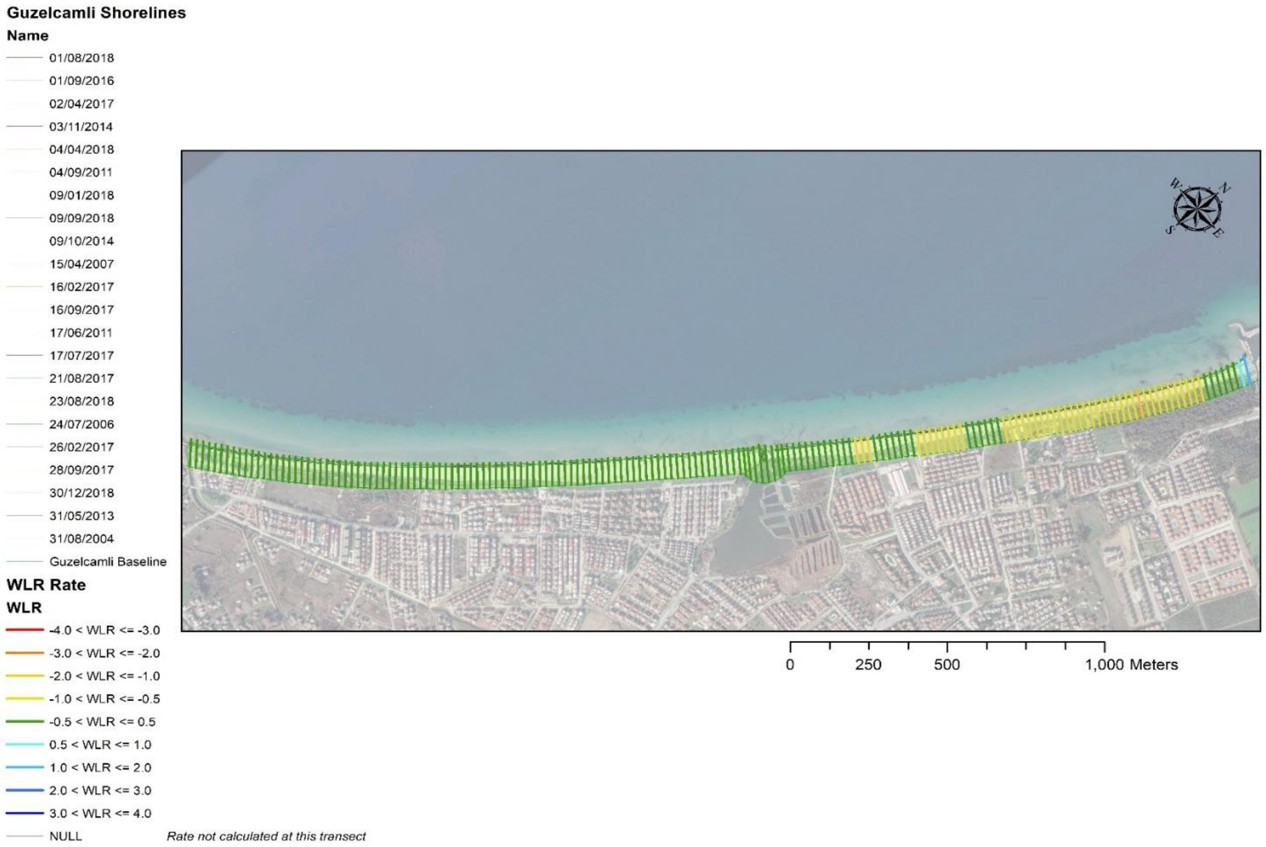

Figure B.32 Güzelçamlı DSAS-WLR Map (ArcMap)

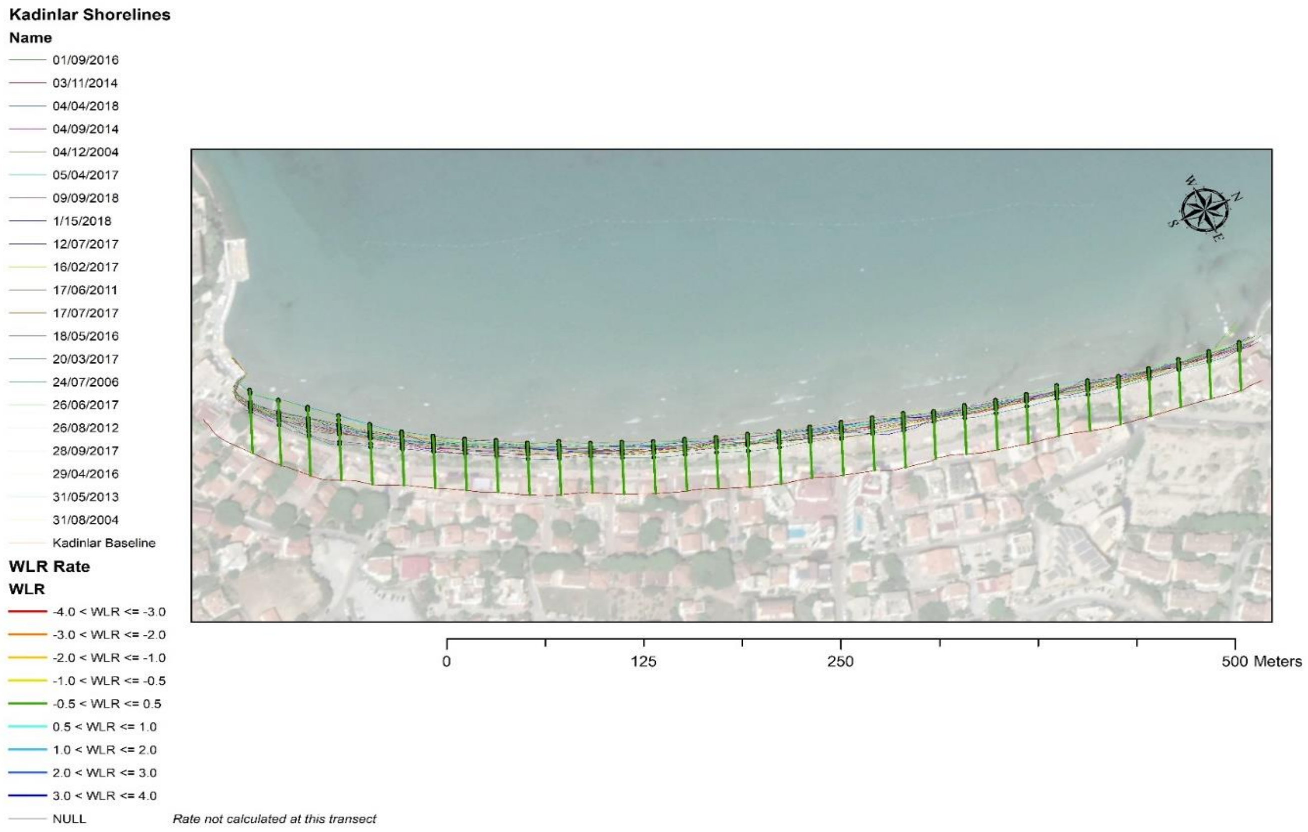

Figure B.33 Kadınlar DSAS-WLR Map (ArcMap)

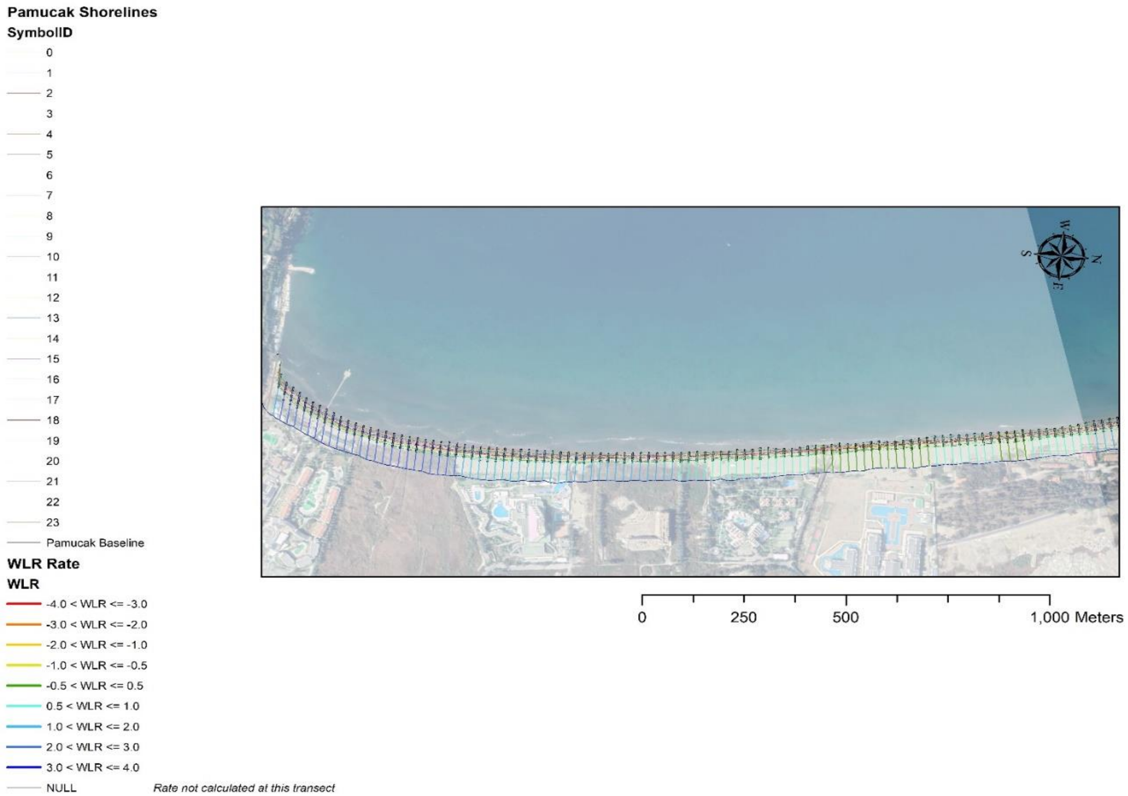

Figure B.34 Pamucak (Section P-1) DSAS-WLR Map (ArcMap)

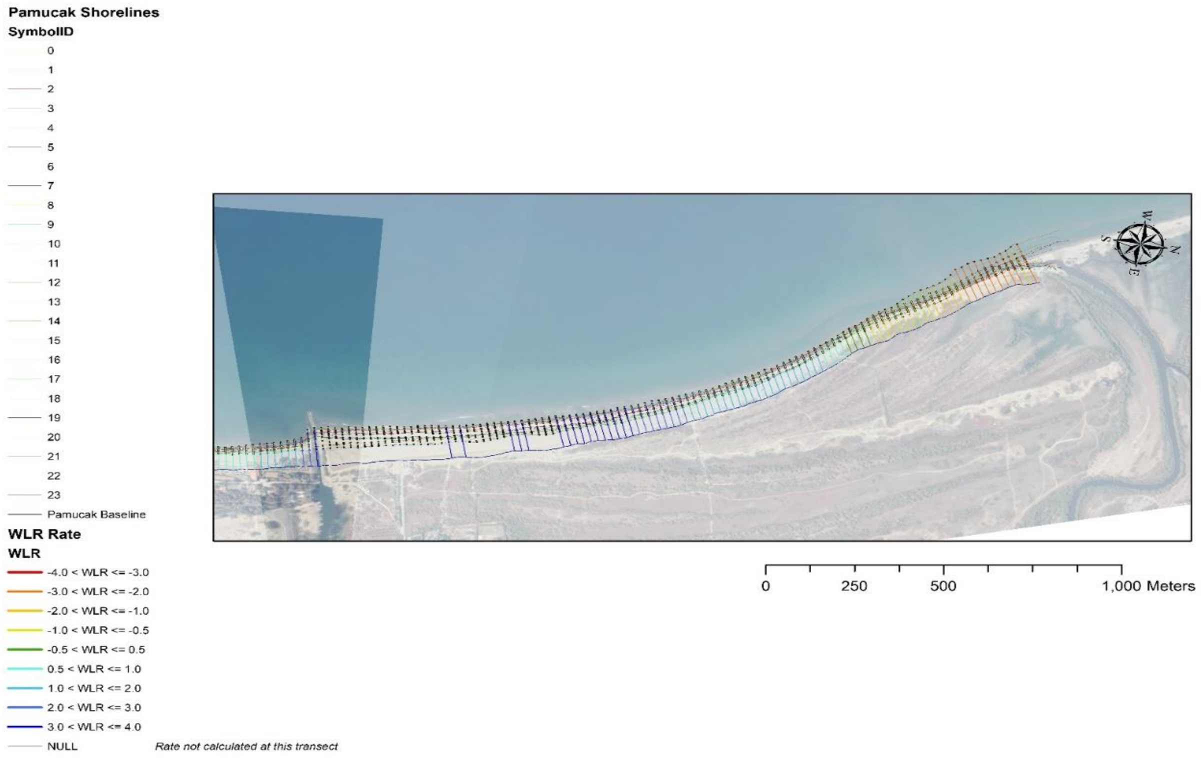

Figure B.35 Pamucak (Section P-2) DSAS-WLR Map (ArcMap)

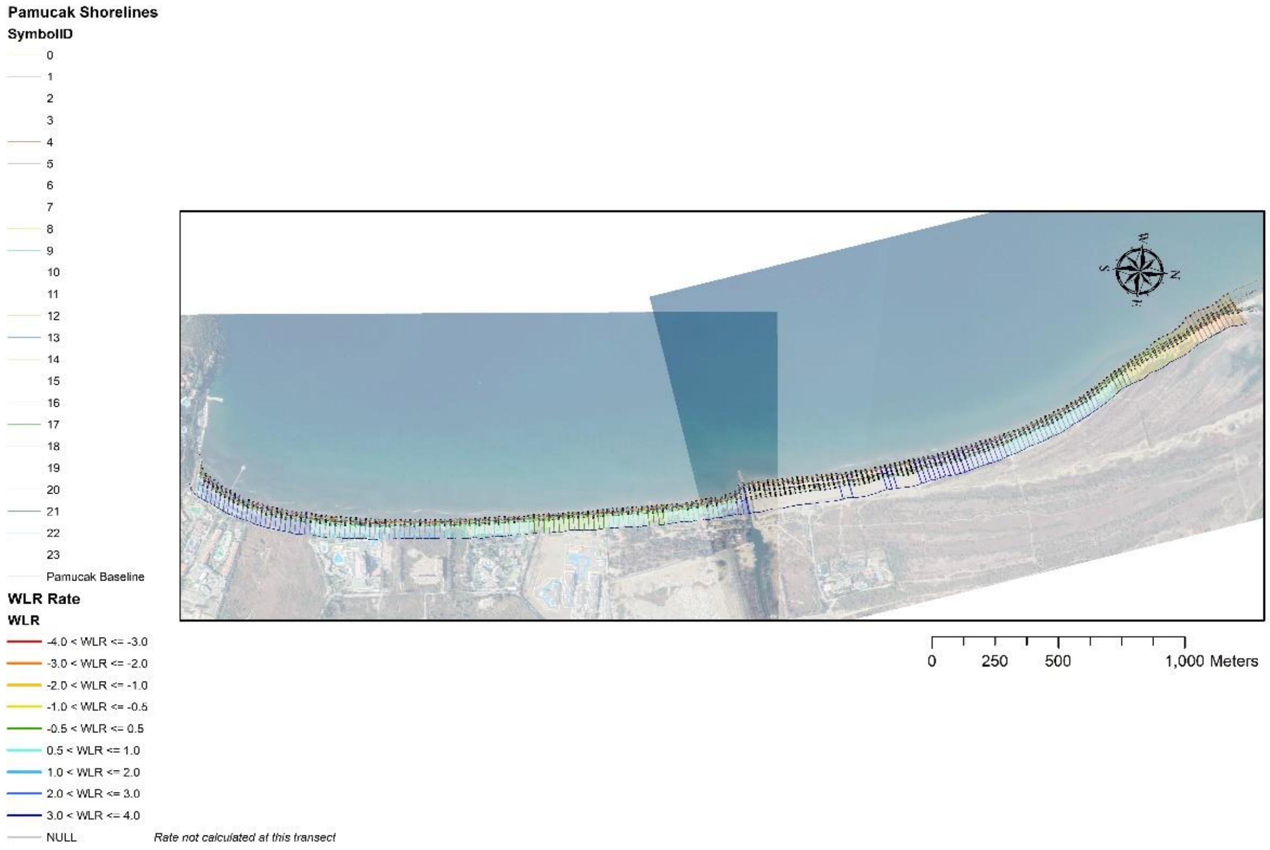

Figure B.36 Pamucak DSAS-WLR Map (ArcMap)

Table B.4 Weighted Linear Regression Rates Results

Beach	*Average rate with reduced uncertainty*	*Percent of all transects that are erosional*	*Percent of all transects that have statistically significant erosion*	*Maximum value erosion*	*Average of all erosional rates*	*Percent of all transects that are accretional*	*Percent of all transects that have statistically significant accretion*	*Maximum value accretion*	*Average of all accretional rates*
Karasu	-0.03 +/- 0.22	45.83	25	-0.5	-0.27	54.17	0	0.3	0.17
Kalamaki	-0.02 +/- 0.25	51.92	0	-0.42	-0.18	48.08	0	0.26	0.14
Aydınlık	-0.23 +/- 0.14	82.5	45	-0.57	-0.29	17.5	0	0.1	0.07
İçmeler	0.43 +/- 0.21	0	0	-	-	100	57.14	0.65	0.43
Güzelçamlı	-0.26 +/- 0.11	84.97	27.57	-1.02	-0.33	15.03	2.89	1.04	0.14
Davutlar	0.31 +/- 0.17	26.86	6.12	-0.94	-0.15	73.14	42.29	2.73	0.48
Kadınlar	0.07 +/- 0.23	24.24	0	-0.16	-0.07	75.76	0	0.21	0.11
Pamucak	1.54 +/- 0.2	12.67	6.33	-2.87	-1.54	87.33	71.04	4.68	1.99

Table B.5 Erosion/Accretion Correction Factors Using DSAS-WLR Rates

Beach	$Cf_{erosion}$
Upper level	1.0106
Karasu	0.9983
Lower level	0.9861
Upper level	1.0329
Kalamaki	0.9971
Lower level	0.9614
Upper level	0.9950
Aydınlık	0.9872
Lower level	0.9794
Upper level	1.0640
İçmeler	1.0430
Lower level	1.0220
Upper level	0.9973
Güzelçamlı	0.9953
Lower level	0.9933
Upper level	1.0137
Davutlar	1.0089
Lower level	1.0040
Upper level	1.0150
Kadınlar	1.0035
Lower level	0.9920
Upper level	1.0268
Pamucak	1.0237
Lower level	1.0206

C. Wave Climate Analysis

Table C.1 Cumulative Frequency in hours

SSE	*S*	*SSW*	*SW*	*WSW*	*W*	*WNW*	*NW*	*NNW*	*N*	*NNE*	*NE*	*ENE*	*E*	*ESE*	*SE*
0	19031	23719	9955	5619	6573	10045	19046	63839	37488	0	0	0	0	0	0
0	11134	13599	6858	3603	4230	6551	11162	45603	25193	0	0	0	0	0	0
0	2059	3406	3571	1774	1935	2715	3290	14946	5832	0	0	0	0	0	0
0	8	533	1770	637	676	673	607	765	305	0	0	0	0	0	0
0	0	140	840	284	145	109	13	0	13	0	0	0	0	0	0
0	0	10	341	178	58	31	0	0	0	0	0	0	0	0	0
0	0	0	133	118	29	9	0	0	0	0	0	0	0	0	0
0	0	0	41	70	3	0	0	0	0	0	0	0	0	0	0
0	0	0	9	36	1	0	0	0	0	0	0	0	0	0	0
0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total Hours = 195315 39 years = 341640

Table C.2 Exceedance Probabilities

H / Dir	*SSE*	*S*	*SSW*	*SW*	*WSW*	*W*	*WNW*	*NW*	*NNW*	*N*	*NNE*	*NE*	*ENE*	*E*	*ESE*	*SE*
0	0	0.055705	0.069427	0.029139	0.016447	0.01924	0.029402	0.055749	0.18686	0.10973	0	0	0	0	0	0
0.4	0	0.03259	0.039805	0.020074	0.010546	0.012381	0.019175	0.032672	0.133483	0.073741	0	0	0	0	0	0
0.8	0	0.006027	0.00997	0.010453	0.005193	0.005664	0.007947	0.00963	0.043748	0.017071	0	0	0	0	0	0
1.2	0	2.34E-05	0.00156	0.005181	0.001865	0.001979	0.00197	0.001777	0.002239	0.000893	0	0	0	0	0	0
1.6	0	0	0.00041	0.002459	0.000831	0.000424	0.000319	3.81E-05	0	3.81E-05	0	0	0	0	0	0
2	0	0	2.93E-05	0.000998	0.000521	0.00017	9.07E-05	0	0	0	0	0	0	0	0	0
2.4	0	0	0	0.000389	0.000345	8.49E-05	2.63E-05	0	0	0	0	0	0	0	0	0
2.8	0	0	0	0.00012	0.000205	8.78E-06	0	0	0	0	0	0	0	0	0	0
3.2	0	0	0	2.63E-05	0.000105	2.93E-06	0	0	0	0	0	0	0	0	0	0
3.6	0	0	0	0	5.56E-05	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	1.46E-05	0	0	0	0	0	0	0	0	0	0	0
4.4	0	0	0	0	2.93E-06	0	0	0	0	0	0	0	0	0	0	0
4.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D. Real Carrying Capacities

Table D.1 RCC of Beaches Using DSAS-WLR Correction Factors

Beach	*RCC, person*
Upper level	326
Karasu	322
Lower level	318
Upper level	357
Kalamaki	345
Lower level	333
Upper level	515
Aydınlık	511
Lower level	507
Upper level	199
İçmeler	195
Lower level	191
Upper level	7895
Güzelçamlı	7879
Lower level	7863
Upper level	24439
Davutlar	24322
Lower level	24205
Upper level	1009
Kadınlar	997
Lower level	986
Upper level	8593
Pamucak	8567
Lower level	8541

Table D.2 RCC of beaches using Bruun Rule (2000-2025)

	Confidence	*SLR, m*	*P-1*	*P-2*	*Kadınlar*	*D-1*	*D-2*	*D-3*	*Güzelçamlı*
RCP 8.5 (2000-2025) & $\Delta x_{Hallermeier}$	*Upper*	*0.12*	2925	3998	0	11345	7539	2323	7816
	Average	*0.1*	3045	4118	0	11491	7770	2429	7833
	Lower	*0.06*	3287	4359	293	11785	8232	2641	7866
RCP 4.5 (2000-2025) & $\Delta x_{Hallermeier}$	*Upper*	*0.11*	2985	4058	0	11418	7654	2376	7824
	Average	*0.08*	3166	4238	59	11638	8001	2535	7849
	Lower	*0.06*	3287	4359	293	11785	8232	2641	7866
RCP 8.5 (2000-2025) & $\Delta x_{Birkemeier}$	*Upper*	*0.12*	2898	4003	0	11345	7670	2311	7872
	Average	*0.1*	3023	4122	0	11492	7879	2419	7880
	Lower	*0.06*	3273	4361	254	11785	8298	2634	7894
RCP 4.5 (2000-2025) & $\Delta x_{Birkemeier}$	*Upper*	*0.11*	2960	4062	0	11418	7775	2365	7876
	Average	*0.08*	3148	4242	7	11638	8089	2527	7887
	Lower	*0.06*	3273	4361	254	11785	8298	2634	7894
RCP 8.5 (2000-2025) & DoC=10 m	*Upper*	*0.12*	2515	4114	274	11311	6930	1996	7561
	Average	*0.1*	2704	4215	394	11464	7263	2157	7620
	Lower	*0.06*	3082	4417	634	11768	7928	2477	7739
RCP 4.5 (2000-2025) & DoC=10 m	*Upper*	*0.11*	2610	4165	334	11387	7096	2077	7590
	Average	*0.08*	2893	4316	514	11616	7595	2317	7679
	Lower	*0.06*	3082	4417	634	11768	7928	2477	7739

Table D.3 RCC of beaches using Bruun Rule (2000-2050)

	Confidence	*SLR, m*	*P-1*	*P-2*	*Kadınlar*	*D-1*	*D-2*	*D-3*	*Güzelçamlı*
RCP 8.5 (2000-2050) & $\Delta x_{\text{Hallermeier}}$	*Upper*	*0.32*	1717	2796	0	9877	5228	1266	7648
	Average	*0.24*	2200	3277	0	10464	6152	1689	7715
	Lower	*0.16*	2683	3757	0	11051	7077	2112	7782
RCP 4.5 (2000-2050) & $\Delta x_{\text{Hallermeier}}$	*Upper*	*0.26*	2079	3156	0	10317	5921	1583	7698
	Average	*0.2*	2442	3517	0	10757	6614	1900	7749
	Lower	*0.16*	2683	3757	0	11051	7077	2112	7782
RCP 8.5 (2000-2050) & $\Delta x_{\text{Birkemeier}}$	*Upper*	*0.32*	1645	2808	0	9878	5579	1232	7799
	Average	*0.24*	2146	3286	0	10465	6415	1664	7828
	Lower	*0.16*	2647	3764	0	11052	7252	2095	7858
RCP 4.5 (2000-2050) & $\Delta x_{\text{Birkemeier}}$	*Upper*	*0.26*	2021	3166	0	10318	6206	1556	7821
	Average	*0.2*	2397	3525	0	10758	6834	1879	7843
	Lower	*0.16*	2647	3764	0	11052	7252	2095	7858
RCP 8.5 (2000-2050) & DoC=10 m	*Upper*	*0.32*	625	3105	0	9788	3605	394	6967
	Average	*0.24*	1381	3509	0	10397	4935	1035	7205
	Lower	*0.16*	2137	3912	33	11007	6265	1676	7442
RCP 4.5 (2000-2050) & DoC=10 m	*Upper*	*0.26*	1192	3408	0	10245	4603	874	7145
	Average	*0.2*	1759	3710	0	10702	5600	1355	7323
	Lower	*0.16*	2137	3912	33	11007	6265	1676	7442

TableD.4 RCC of beaches using Bruun Rule (2000-2075)

	Confidence	*SLR, m*	*P-1*	*P-2*	*Kadınlar*	*D-1*	*D-2*	*D-3*	*Güzelçamlı*
RCP 8.5 (2000-2075) & $\Delta x_{\text{Hallermeier}}$	*Upper*	*0.65*	0	811	0	7455	1416	0	7371
	Average	*0.45*	932	2014	0	8923	3726	578	7539
	Lower	*0.35*	1536	2615	0	9657	4881	1107	7623
RCP 4.5 (2000-2075) & $\Delta x_{\text{Hallermeier}}$	*Upper*	*0.5*	631	1713	0	8556	3149	314	7497
	Average	*0.38*	1355	2435	0	9437	4535	948	7597
	Lower	*0.28*	1959	3036	0	10170	5690	1477	7681
RCP 8.5 (2000-2075) & $\Delta x_{\text{Birkemeier}}$	*Upper*	*0.65*	0	837	0	7458	2128	0	7678
	Average	*0.45*	831	2032	0	8925	4219	531	7751
	Lower	*0.35*	1457	2629	0	9658	5265	1070	7788
RCP 4.5 (2000-2075) & $\Delta x_{\text{Birkemeier}}$	*Upper*	*0.5*	518	1733	0	8558	3697	261	7733
	Average	*0.38*	1269	2450	0	9438	4951	909	7777
	Lower	*0.28*	1896	3047	0	10172	5997	1448	7814
RCP 8.5 (2000-2075) & DoC=10 m	*Upper*	*0.65*	0	1440	0	7274	0	0	5988
	Average	*0.45*	0	2449	0	8798	1444	0	6582
	Lower	*0.35*	341	2954	0	9559	3106	153	6878
RCP 4.5 (2000-2075) & DoC=10 m	*Upper*	*0.5*	0	2197	0	8417	613	0	6433
	Average	*0.38*	58	2802	0	9331	2608	0	6789
	Lower	*0.28*	1003	3307	0	10093	4270	714	7086

Table D.5 RCC of beaches using Bruun Rule (2000-2100)

	Confidence	*SLR, m*	*P-1*	*P-2*	*Kadınlar*	*D-1*	*D-2*	*D-3*	*Güzelçamlı*
RCP 8.5 (2000-2100) & $\Delta x_{\text{Hallermeier}}$	*Upper*	*1.08*	0	0	0	4300	0	0	7009
	Average	*0.8*	0	0	0	6354	0	0	7245
	Lower	*0.54*	389	1473	0	8262	2686	102	7463
RCP 4.5 (2000-2100) & $\Delta x_{\text{Hallermeier}}$	*Upper*	*0.74*	0	270	0	6795	376	0	7295
	Average	*0.52*	510	1593	0	8409	2917	208	7480
	Lower	*0.38*	1355	2435	0	9437	4535	948	7597
RCP 8.5 (2000-2100) & $\Delta x_{\text{Birkemeier}}$	*Upper*	*1.08*	0	0	0	4304	0	0	7519
	Average	*0.8*	0	0	0	6358	560	0	7622
	Lower	*0.54*	267	1494	0	8265	3278	46	7718
RCP 4.5 (2000-2100) & $\Delta x_{\text{Birkemeier}}$	*Upper*	*0.74*	0	299	0	6798	1187	0	7644
	Average	*0.52*	393	1613	0	8411	3488	154	7725
	Lower	*0.38*	1269	2450	0	9438	4951	909	7777
RCP 8.5 (2000-2100) & DoC=10 m	*Upper*	*1.08*	0	0	0	3999	0	0	4713
	Average	*0.8*	0	684	0	6132	0	0	5543
	Lower	*0.54*	0	1995	0	8112	0	0	6315
RCP 4.5 (2000-2100) & DoC=10 m	*Upper*	*0.74*	0	986	0	6589	0	0	5721
	Average	*0.52*	0	2096	0	8265	280	0	6374
	Lower	*0.38*	58	2802	0	9331	2608	0	6789

Table D.6 RCC of beaches using Bruun Rule (2000-2025)

		SLR, m	*P-1*	*P-2*	*Kadınlar*	*D-1*	*D-2*	*D-3*	*Güzelçamlı*
Menteş (1986-2001) & $\Delta x_{\text{Hallermeier}}$	*upper confidence*	0.18	2562	3637	0	10904	6846	2006	7765
	average	0.16	2713	3788	817	11088	7134	2138	7786
	lower confidence	0.13	2864	3938	525	11271	7423	2271	7807
Mentes (1986-2001) & $\Delta x_{\text{Birkemeier}}$	*upper confidence*	0.18	2522	3644	0	10905	7043	1987	7850
	average	0.16	2678	3794	919	11088	7304	2122	7860
	lower confidence	0.13	2835	3943	610	11272	7566	2257	7869