ICONARP
International Journal of Architecture and Planning
Received: 18.01.2022 Accepted: 08.03.2022
Volume 10, Issue 1/ Published: 30.06.2022
Research Article
DOI: 10.15320/ICONARP.2022.205 E- ISSN:2147-9380
ICONARP

Ecological Memory and Socio-Ecological Resilience Approach Within the Scope of Muğla Wildfires

Burak Beyhan*
Feray Koca**

Abstract

The climate change crisis stemming from anthropogenic reasons has triggered severe weather events and disasters all over the world in recent years. In this context, the main purpose of the paper is to reveal the importance of ecological memory in the face of the wildfires threatening our living spaces and taking place between 29 July-12 August 2021 throughout Muğla Province, and to divulge basic strategies for the future of the region by questioning the resilience of ecosystem. The damage caused by wildfires are determined by using satellite images and remote sensing methods in GIS. Accordingly, the borders of burned areas were determined by using mainly remote sensing data according to the degree of burn severity on the basis of NBR. In turn, these borders were overlapped with CLC data and administrative borders at different scales for determination of the land cover types of the burned areas and the urban areas affected. Subsequently, the actual surface areas of the burned regions were calculated by using SRTM GL1 satellite images. The results show that not only forest assets, but also agricultural areas, production areas, mining areas, urban transportation network and residential areas were damaged by the wildfires. Although burned areas can be calculated by using remote sensing methods as done in this study, exact delimitation of fire zones and precise distribution of the burned areas according to land cover types also require in-situ work. Hence, the scope of the paper doesn't cover these issues that can only be addressed by future studies. Overall, the paper proposes a framework for questioning the socio-ecological resilience of the ecosystem in the upcoming period of the disasters that threaten our living spaces, and formulates a set of strategies for spatial planning by employing a socio-ecological approach for increasing the resilience of habitats by revealing ecological memory.

Keywords:
Ecological memory, ecosystem, Muğla, resilience, wildfires

*Faculty of Architecture, Muğla Sıtkı Koçman University, Muğla, Türkiye
Email: burakbeyhan@mu.edu.tr

**Faculty of Architecture, Muğla Sıtkı Koçman University, Muğla, Türkiye
(*Corresponding author*)
Email: feraykoca@mu.edu.tr

To cite this article: Beyhan, B., & Koca, F. (2022). Ecological Memory and Socio-Ecological Resilience Approach Within the Scope of Muğla Wildfires, ICONARP *International Journal of Architecture and Planning,* 10 (1), 325-348. DOI: 10.15320/ICONARP.2022.205

INTRODUCTION

In the last century, climate change, which has emerged as a result of the increase in greenhouse gas emissions to atmosphere due to the industrialization and urbanization, causes negative ecological impacts and deteriorations all over the world and threatens our living spaces. While climate change triggers severe weather events and disasters such as heat waves, drought, desertification, floods, and wildfires, it also changes the frequency, intensity and spatial scale of these disasters. It is known that in the face of anthropogenic climate change the responses of ecosystems fluctuate according to the extreme events and disruptions in the past, and this situation creates an ecological memory loss for the ecosystem. With the increasing alterations and losses in the Anthropocene epoch, ecological memory is at risk of not finding the opportunity to renew itself. In this context, in recent years, scientists have been trying to develop a set of strategies to increase the resilience of habitats by revealing ecological memory and predicting future ecosystem reactions.

Ecological memory is defined as the ability of an ecosystem's past evolutionary history and experiences to influence future ecological responses of the ecosystem. The genetic inheritance contained in the ecosystem provides it with a self-healing and self-reproductive ability by increasing its resilience. The nature as a self-organizing system has an inner resilience capacity. However, the change in environmental conditions caused by the increase in industrialization and urbanization and the global climate crisis have weakened the sustainability of this inheritance (Johnstone et al., 2016). Therefore, identifying the ecological inheritance that supports the resilience of the ecosystem will help constitute the right supports by making consistent predictions against the climate change crisis that threatens the ecosystems and settlements today.

The aim of this article is to put forward the basic strategies for the future resilience approach by revealing the loss of ecological inheritance that constitutes the ecological memory by determining the types and sizes of the burned and damaged land through satellite photographs because of the severe wildfires that continued for approximately 15 days between July 29 and August 12 of 2021 in Muğla Province. Especially in the settlements located in the burned areas of Muğla, the fact that human livelihoods depend on the forest structure and its function makes it much more important for us to have a resilient forest ecosystem robust to a variety of shocks, deterioration and changes.

The spatial spread of human actions brought by urbanization has resulted in deterioration of the balance of built and natural environment. These anthropogenic disturbances, unlike the natural climatic changes that took place throughout the evolution of the world, can weaken the self-renewal ability of ecosystems and even trigger permanent changes on the ecosystem. In this respect, it is claimed that we are in a new geological process called Anthropocene, since the damages caused by

DOI: 10.15320/ICONARP.2022.205

anthropogenic pollution are also recorded within the geological processes (Sümer et al., 2020). This process takes the 21st century resilience debates one step further from the basic resilience approach that advocates the preservation of natural resource stability, towards an adaptive resilience approach that can help overcome the ecological collapses caused by the mismanagement of societies and the increasing human demand on the ecosystem (McWethy et al., 2019).

Parallel to these considerations, wildfires in Muğla, which are the focus of this article, arisen as a result of the deterioration of the natural environment. While the increasing population and the excessive intervention of human actions in forests cause a decrease in forest areas, the deteriorated ecosystem accelerates the transition to a more arid climate, thus increasing the frequency and severity of fires. As the risk of wildfires based on climate change increases from year to year, it is argued that new strategies should be put forward to ensure the economic recovery of communities that make a living from burned forest areas, to increase the resilience of the ecosystem and to ensure justice for the environment. In this context, The Nature Conservancy, a global environmental organization, stated in its report that wildfires require a paradigm shift (1) to significantly increase investments in all forest studies-related programs, (2) to emphasize the avoided costs, public interest and common benefits of wildfire resilience studies, (3) to adopt a holistic, strategic approach to address the scale of needs instead of an incremental and piecemeal approach (Clavet et al., 2021).

In this report, in order to increase resilience, a number of strategies such as creating employment, enabling the economic development of society, advancing environmental justice, protecting infrastructure, ensuring healthy watersheds and supply, supporting the conservation of green spaces, restoring wildlife habitat, creating opportunities for outdoor activities, protecting forest and soil carbon, developing natural and arable land solutions against climate change have been proposed for preservation of the social, economic and ecological co-benefit value. Socio-ecological resilience studies gain importance when determining strategies ranging from effective pre-fire planning to how wildfires are managed and even living with fire (Thompson et al., 2016). In the case of wildfires, resilience studies focus on understanding the relationship between the increasing frequency and severity of wildfires as a result of climate change and the ability of policy and management paradigms to help ecosystems and rural communities adapt to social-ecological change (Selles et al., 2020).

Within the scope of this study, in the next section, the method of analysis for the detection of the damage caused by the wildfires, which occurred suddenly and severely in the province of Muğla, will be explained in order to reveal the ecological memory that will be the basis for resilience studies. In the subsequent sections, first, an evaluation will be made on the land cover, severity of the damage on the identified fire zones and the impact on the human settlements at the neighbourhood level for exposition of the basic clues regarding the general framework of the socio-ecological resilience approach, and then the strategies that can be followed through these clues will be discussed. In the conclusion part, zone-specific suggestions have been developed to re-evaluate the damages caused by wildfires and to increase socio-ecological resilience based on the strategies discussed.

METHOD AND DATA

In the study, NASA's Landsat 8 (30m) and Shuttle Radar Topography Mission (SRTM) GL1 (30m) satellite images and CORINE Land Cover (CLC) 2018 vector files were used. Landsat 8 satellite images were used to determine the burned areas and degree of burning, SRTM GL1 images were used to calculate the actual surface areas and CLC data were used to determine the pre-fire land cover in the fire damaged areas. Administrative borders used in the study were compiled from the provincial and district borders downloaded from the website of the General Directorate of Mapping. The neighbourhood boundaries obtained from the Muğla Metropolitan Municipality were used for the summary tables compiled on the basis of villages and neighbourhoods regarding the fire areas. The data used in the study were analysed and visuals were produced by using Free and Open Source Software (FOSS) for Geographic Information Systems (GIS) such as Quantum GIS (QGIS) and SAGA (2021), and the special plug-ins in these software packages. In this context, the Semi-Automatic Classification Plugin (SCP) plugin (Congedo, 2021) and output editor in QGIS (2021) were used effectively, especially for preprocessing of images used in the paper.

The raster image created in QGIS by using the bands 4 (Red), 3 (Green) and 2 (Blue) of the Landsat 8 satellite images taken after the wildfires in Muğla can be seen in Figure 1.

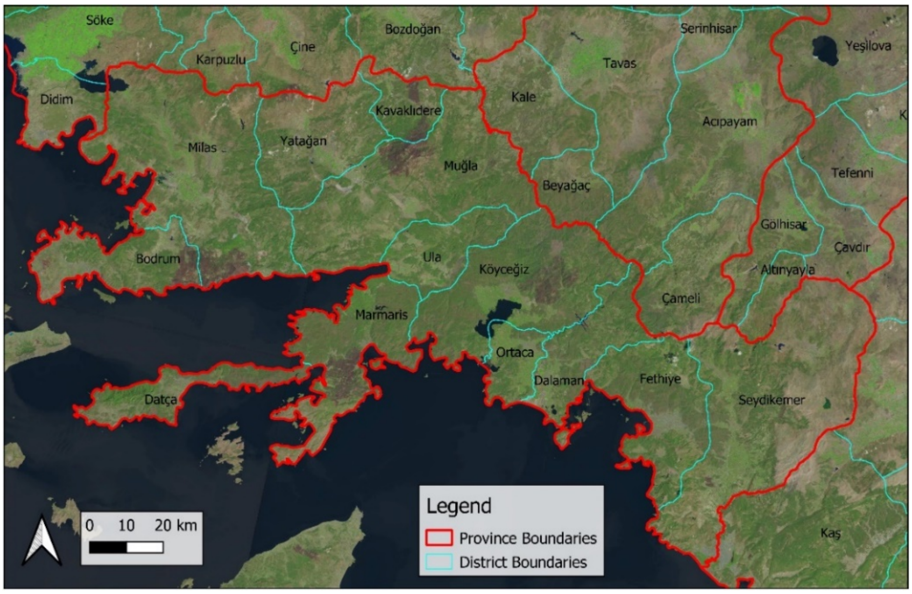

Figure 1. Raster image of Muğla province, created by using Landsat 8 satellite images taken between 14 and 21 August 2021, after the fires.

In this image, although the fire areas are clear as large areas that can be visually distinguished by the brown colour, there are well established

DOI: 10.15320/ICONARP.2022.205

methods such as those using Normalized Burn Ratio (NBR) index developed for more precise analysis. In this context, the workflow used in the method of detection of burned areas in this study can be seen in Figure 2. The first step in the workflow is the acquisition of satellite images of the burned areas before and after the fire. The dates before and after the fire are extremely important, and as long as possible, should correspond to, respectively, just before and after the fire. Landsat-8 images before and after the fire for the whole of Muğla on 13 & 20 July 2021 and 14 & 21 August 2021, respectively, were downloaded from the USGS (United States Geological Survey) Earth Explorer's website (https://earthexplorer.usgs.gov/).

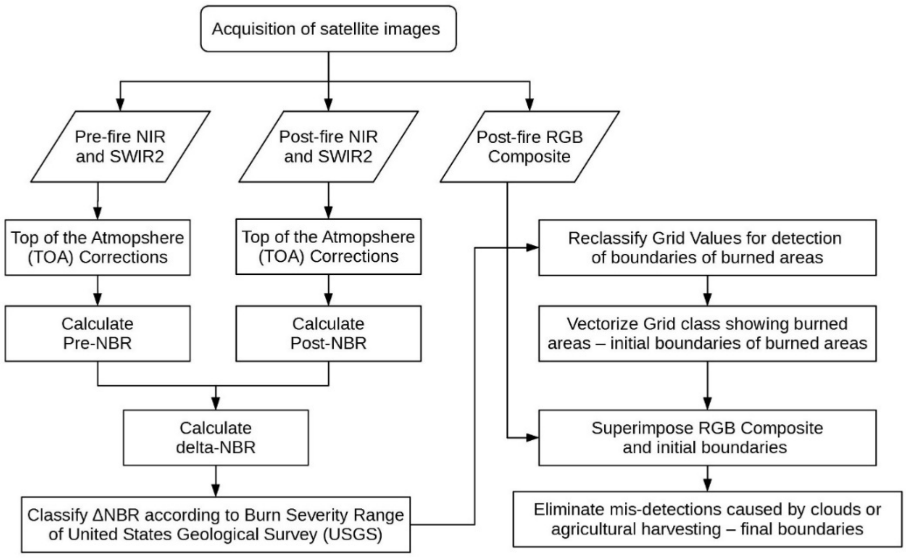

Figure 2. Workflow used in the detection of burned areas in the study.

Normalized Burn Ratio (NBR) index is widely used in the determination of both burned areas and burning severity. In turn, the results of NBR analysis can be used to design policies and strategies to mitigate effects of the wildfires in terms of helping the ecosystem sustain its resilience and maintain its memory. For example, in their study, Strand et al. (2019) use the difference NBR to understand the dynamics and resilience of forest floor vegetation in the ecosystems experiencing wildfires.

By analysing the recovery processes in seven wildfire areas in the USA after one decade following the fires, Strand et al. (2019) demonstrate that plant communities in the forest floor were not deeply transformed by the wildfires that have in fact resulted in the increasing diversity of species, which, according to them, suggests that the wildfires with low to moderate burn severity actually contribute to the long-term care of a diverse and productive forest floor. Although, in terms of ecological resilience, this result confirms the fact that the nature can take care of itself, a socio-ecological framework should take the social implications of wildfires into account, as suggested in this study. In this context, it is important to emphasize that NBR index help us quickly expose the extent of the damage caused by the wildfires. This is as valuable as the post-fire evaluations made after a relatively long time period for testing the recovery process in the ecological system.

In terms of socio-ecological perspective, this is particularly valuable in understanding both couples of the resilience framework; the social and the ecological systems. As being part of the ecological system, in the forest resilience framework formulated by Johnstone et al. (2016), the centre of attention is ecological resilience in terms of adaptation of forests to a specific historical disturbance regime that can be defined as the patterns of disturbance characterized by regularity, severity, extent, or other attributes. In this framework, ecological memory is composed of two components (Johnstone et al., 2016): (1) information legacies of evolutionary adaptations to a disturbance regime and (2) material legacies (such as seeds, dead trees in an ecosystem after a disturbance event). While the former arises over long time periods with wide spatial scales, the latter rises on short time periods with local spatial scales.

The method of analysis used in this study allows us to draw the context for one of the important disturbances occurred recently in Muğla in terms of expectations for information and material legacies in connection with their social implications. As the prediction of responses of the ecosystem is a complex process, this contextualization provides us with the possible extent of the loss and the risk associated with resilience debt which is defined by Johnstone et al. (2016) as a loss of resilience because of the failure of system in the alignment of information legacies with disturbance. As Peterson (2002) remarks, once ecological memory is vigorous and ecological pattern is stable, pattern tends to be sustained rather than demolished by the wildfire. It is the ecological memory that allows processes for the re-production of ecological pattern.

However, if the magnitude of disturbances is huge, as in the case of recent wildfires in Muğla, it may alter the disturbance regime, and subsequently lead to resilience debt. The extent of resilience debt can be drawn in relation to the safe operating space used by Johnstone (2016: 370) to refer "to biophysical planetary boundaries within which human societies can continue" to progress and prosper. The safe operating space framework can be used for contemplation of interactions of disturbance characteristics and environmental conditions with the components of ecological memory increasing the resilience of forests to disturbance. The method of analysis used in this study actually helps us expose the material evidence to question the creation of resilience debt and its relation with safe operating space.

Because of the vast wildfires, today, it can be argued that in many parts of the world safe operating space is endangered. Combined with the large wildfires, the interaction between climate change, invasive species, and land-use have resulted in the erosion of ecological memory, which has generated a strong interest in regenerating natural processes to mitigate the negative effects of current changes on human eco-cultural & social relationships, and in the contextualization of long-term anthropogenic factors (Eisenberg et al., 2019). During this process, Traditional

DOI: 10.15320/ICONARP.2022.205

Ecological Knowledge (TEK) has particularly gained importance and been rediscovered as a help to create ecosystems more resilient to wildfires and subsequent negative effects (Eisenberg et al., 2019).

The extent and the degree of the damage caused by the recent disturbance in the socio-ecological system in Muğla can be analysed by delimiting the areas damaged together with the degree of harm, and in turn, by exposing the attributes of material loss having importance in ecological memory. It is within this context that NBR index provides us with the material evidence for exposition of the damage caused by the recent wildfires. Landsat 8 satellite images used in the calculation of NBR index consist of nine spectral bands with a spatial resolution of 30 meters except for Band 8 (panchromatic) whose resolution is 15 meters, and thermal bands 10 and 11 providing accurate surface temperatures and having a resolution of 100 meters. Among them, Near Infrared (NIR) (Band 5) and Short Wave Infrared (SWIR) (Band 7) bands of the spectrum are needed to calculate the NBR (Figure 3).

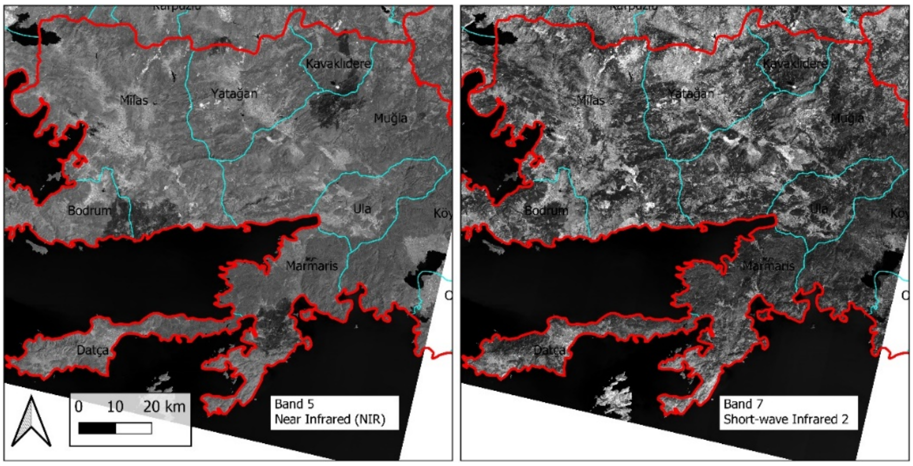

Figure 3. Bands 5 and 7 in Landsat 8 satellite images taken for the western part of Muğla on August 21, 2021.

It is known that the newly burned areas show low reflection in the NIR part of the spectrum and high reflection in the SWIR part of the spectrum, while in healthy vegetation it shows high reflection in NIR part of the spectrum and low reflection in SWIR part of the spectrum. In other words, the difference between the spectral responses of healthy vegetation and burnt areas peaks in NIR and SWIR parts of the spectrum. In this context, NBR is calculated as follows (Equation 1) (Key et al., 2002; Pepe and Parente, 2018; Saulino et al., 2020):

$$NBR = \frac{\text{NIR} - \text{SWIR 2}}{\text{NIR} + \text{SWIR 2}} \qquad \text{Equation 1}$$

NBR can take a value between -1 and +1 (Nasery and Kalkan, 2020). In the method used, using this equation, the images of NBR just before and just after the fire are calculated (Figure 4). However, before making these calculations, it is recommended to perform the Top of the Atmosphere

(TOA) corrections on the raw Band 5 and Band 7 data (Figure 2). Especially since smoke aerosols have significant effects, it is necessary to correct the reflection of the TOA to the surface reflection in order to apply the burnt area mapping algorithm reliably (Roy et al., 2019). Atmospheric correction is one of the basic procedures applied before the calculations of the NBR (see, for example, Pepe and Parente, 2018; Polat and Kaya, 2021). In this context, atmospheric correction in this study was performed by using SCP plugin (Congedo, 2021) in QGIS for Landsat preprocesses.

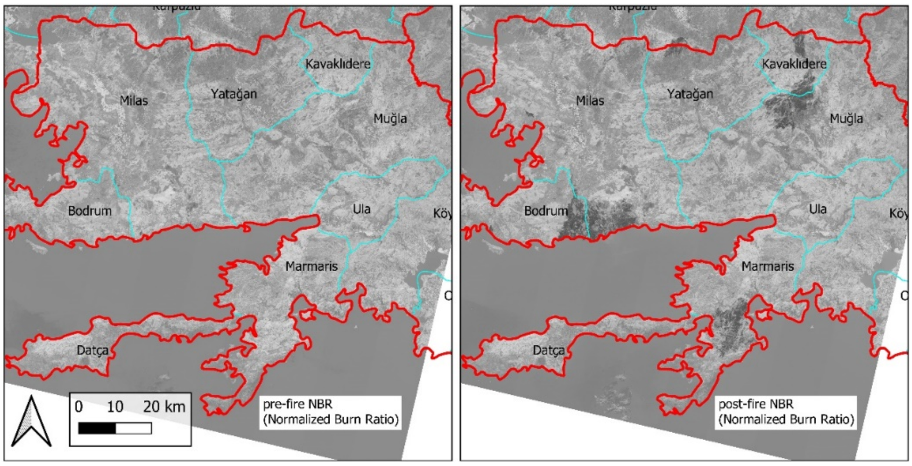

Figure 4. Pre-fire and post-fire NBR images calculated by using Landsat 8 satellite images taken for the western part of Muğla between 13 & 20 July 2021 and 14 & 21 August 2021.

In order to distinguish the burnt areas from the unburned areas and to provide a quantitative measure of the change, the NBR image calculated for the post-fire is subtracted from the NBR image calculated for the pre-fire (Equation 2) and the difference image (ΔNBR) (Figure 5) is obtained. (Key et al., 2002; Key & Benson, 2006; Nasery & Kalkan, 2020; Saulino et al., 2020):

$$\Delta NBR = \text{Pre\_fire NBR} - \text{Post\_fire NBR} \qquad \text{Equation 2}$$

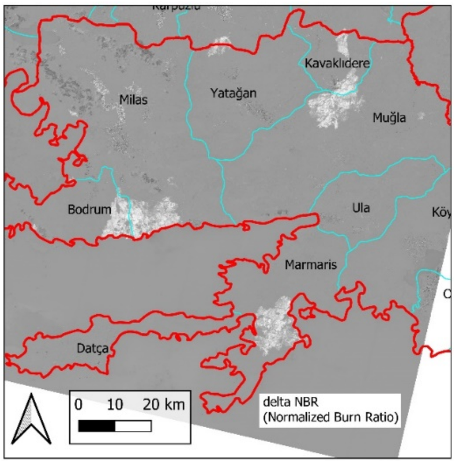

Figure 5. The western part of Muğla for ΔNBR images calculated by using Landsat 8 satellite images taken between 13 & 20 July 2021 and 14 & 21 August 2021.

Although various maximum and minimum ΔNBR values can be observed for different cases, a ΔNBR greater than a certain threshold

DOI: 10.15320/ICONARP.2022.205

indicates burning and higher values of dNBR indicate more severe damage. In this respect, ΔNBR is also used as a measure of burn severity despite variable results (Key & Benson, 2006; Roy et al., 2019). Indeed, from an optical point of view, a drastic reduction in visible and NIR surface reflection is observed when vegetation is burned. In this context, although empirical studies vary according to needs, burn severity is operationally defined as the loss or change of aboveground and underground organic matter (Keeley, 2009). The depth of respective change is related to the burn severity on vegetation and is captured as a change in the value of the spectral indexes. In fact, NBR has also been developed for this purpose and is typically used as ΔNBR between pre-fire and post-fire conditions (Saulino et al., 2020). Thus, the damage caused by the fire can be used to show the degree of burning such as low, moderate-low, moderate-high and high severity. In this study, the degree of burn was associated with ΔNBR according to the classification proposed by the United States Geological Survey (USGS) (Sobrino et al., 2019; Lutes et al. 2006) (Figure 6). There is also a ΔNBR classification recommended by the European Forest Fire Information Service (EFFIS) (Llorens et al., 2021). Actually, there is no fundamental difference between the two classifications.

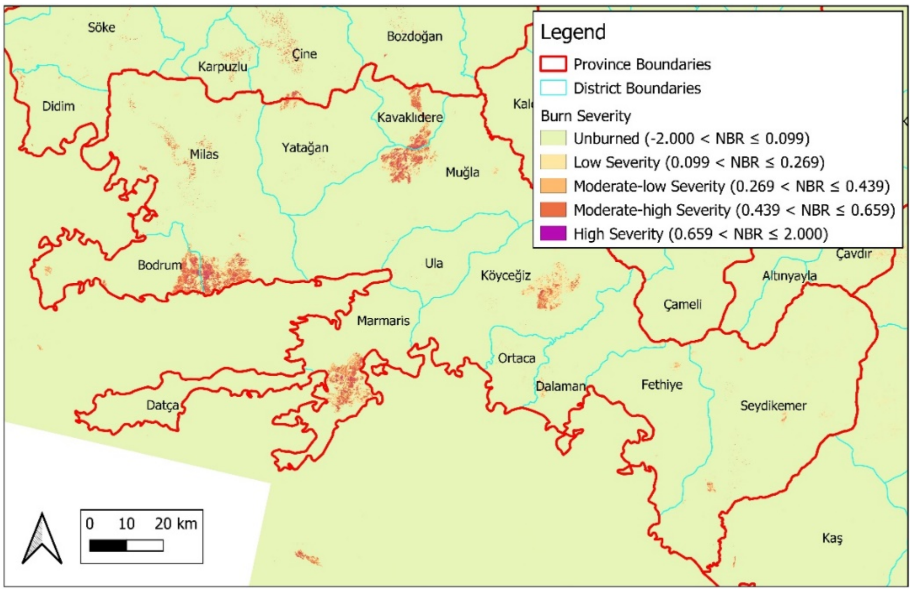

Figure 6. Thematic map showing the damage caused by wildfires in Muğla between 29 July and 12 August 2021.

When the ΔNBR data used in the production of Figure 6 is carefully examined, it can be seen that although there is no fire in some small areas, the range of value in these areas remains within the scale defined for the fire areas. For example, although none of the recent fires were within the boundaries of Fethiye district, a small area in Fethiye looks as if it was burned. It is known that such situations are caused by reasons such as the fact that the sky is cloudy in the respective places during the periods when satellite photographs are taken, or that it coincides with agricultural harvest periods. Indeed, when examined in detail, it was concluded that the situation in Fethiye was caused by the clouds.

Therefore, in order to determine the boundary of the fire areas more accurately, the ΔNBR data was reclassified by using “Reclassify Grid Values” tool in SAGA for delimitation of only the areas with fire, and the resulting image was vectorized by using “Vectorizing Grid Classes” tool of again SAGA. Later, these boundaries were superimposed on Figure 1 for elimination of the misdetections caused by clouds or agricultural harvesting (Figure 2). As a result of this process, the fire zone boundaries shown in Figure 7 were obtained. A close examination of Figure 7 reveals the fact that there are small unburned areas in the burned areas. Those small unburned areas are actually a centre of attention for some researchers owing to the fact that as being areas unaffected from the fire they are considered as fire refugia having potential for regeneration of the forest from the ashes of the old one (see, for example, Walker et al., 2019).

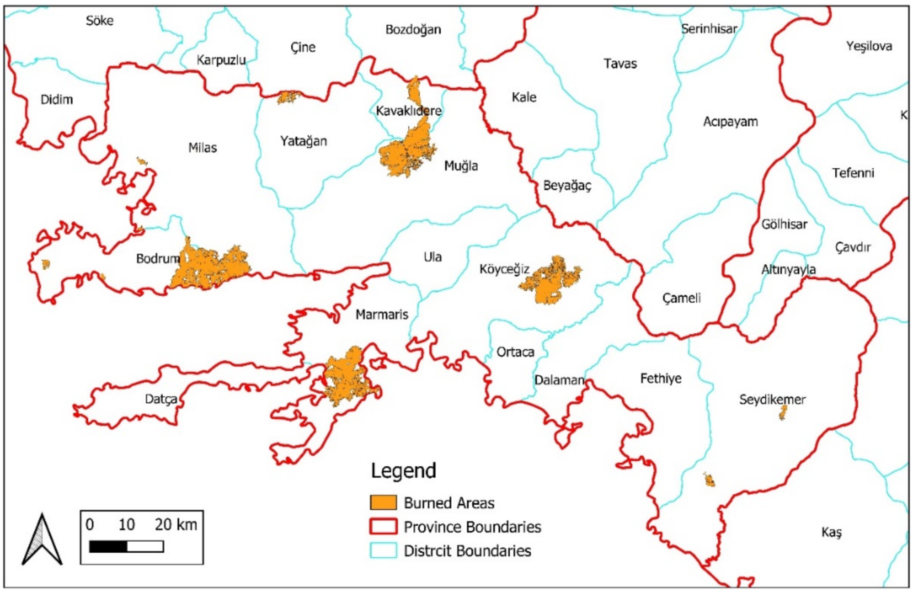

Figure 7. Wildfire zones in Muğla between 29 July and 12 August 2021.

After delimitation of wildfire zones and levels of burn severity, another workflow is used in the study for the production of information in relation to the overlap between the boundaries of wildfire zones & levels of burn severity and the boundaries of land cover types & administrative units (Figure 8). For this purpose, first of all, polygon overlay analysis was performed by intersecting the borders in Figure 7 with the CLC 2018 vector data using the “Intersect” tool in SAGA, and the borders of the burned areas were created according to the land cover types in 2018. Subsequently, the real surface area grid of the entire Muğla province was created by using “Real Surface Area” tool in SAGA and the SRTM GL1 data compiled for Muğla. Consequently, the amount of burned areas left in the fire zones and in the other sub-zones resulting from different polygon overlap analyses was determined by using “Grid Statistics for Polygons” tool of SAGA and the grid concerned. The tables used in the analyses in the next section were produced by using these tools.

DOI: 10.15320/ICONARP.2022.205

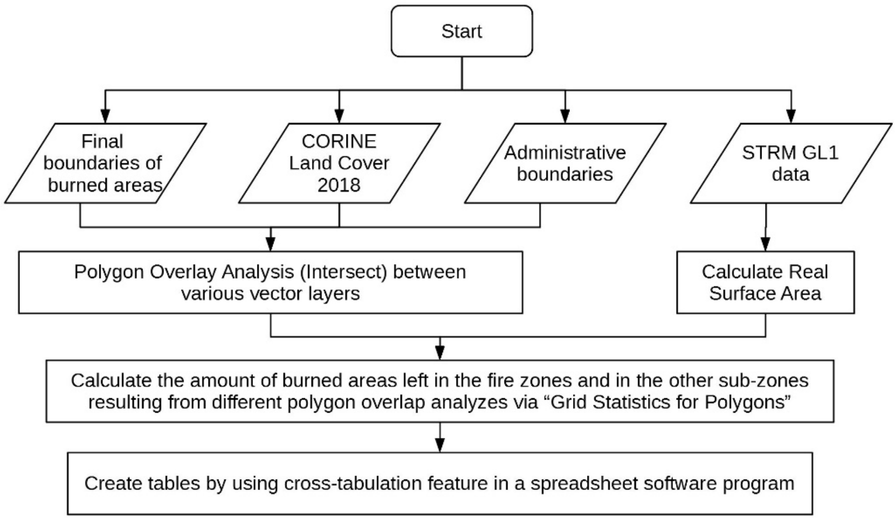

Figure 8. Workflow used in the creation of the summary tables in the study.

ELABORATION OF THE AREAS DAMAGED BY WILDFIRES IN MUĞLA

Severe wildfires, which first started on July 29, 2021 in Armutalan Neighbourhood of Marmaris District and spread in different districts and neighbourhoods in the subsequent days, uninterruptedly grew for about 15 days and damaged large areas of land and neighbourhoods in Muğla province. The fires that caused the burning of rural settlements were titled as 'orman yangını' (forest fires) in Turkish because the fires started in the forest area and burned a large amount of forest land. However, in English, the word 'wildfires' is used for such fires. In addition, since the fires started in the forest area and the institutions that will respond to the fire in the division of authority in Turkey are defined according to the area of origin and spread of the fire, it can be argued that 'orman yangını' can be considered to be more appropriate to describe the related fires in Turkish context.

In order to understand the damage caused by forest fires in Muğla province, it is necessary to define the climatic conditions and vegetation of the geography. Muğla province has a Mediterranean scrub and forest biome under the influence of subtropical Mediterranean climate. While there are forests of mixed species of red pine, oak, larch and juniper up to 2000 meters and above in Muğla, there are bare rocky and/or open areas in areas higher than 2200 meters. A large part of the vegetation cover consists of red pines. Especially in areas with degraded red pine forests around settlements, scrub vegetation has developed over time and has become permanent (Türkeş and Altan, 2013). In Muğla, the total forest area was determined as 829,309 ha (874,254 ha according to CLC 2018 – including 'Transitional woodland-shrub' and 'Sclerophyllous vegetation') before the wildfires by the General Directorate of Forestry in Muğla and it constituted 68% of the total area in the province (OGM, 2021).

The sizes and locations of the wildfire zones identified in Figure 7 are superimposed on top of the map showing the administrative boundaries in Muğla province. Within the scope of this study, the wildfires that spread with different severity and intensity in Muğla were grouped under

7 fire zones that were titled as (1) Mazı-Ören, (2) Bodrum-Milas General, (3) Yatağan, (4) Menteşe-Kavaklıdere, (5) Marmaris, (6) Köyceğiz and (7) Seydikemer. These zones can be grouped into two general categories. The first one covers zones of wildfire uninterruptedly combining very large areas. Mazı-Ören, Köyceğiz, Menteşe-Kavaklıdere, and Marmaris wildfires fall into this category. The second category covers zones of relatively smaller areas disconnected from each other. Bodrum-Milas General, Yatağan and Seydikemer wildfires fall into this second category.

The size of areas in different fire zones according to the burn severity in low, moderate-low, moderate-high and high severity categories are given in Table 1. In total, 57,153.90 ha land in Muğla was burned in the last wildfires. According to the news published on August 9, 2021, a total of 66,000 hectares of land was burned in different districts of Muğla (Cumhuriyet Gazetesi, 2021; Sözcü Gazetesi, 2021). However, since natural disasters progress regardless of the provincial and district boundaries, it would be more appropriate to elaborate the damage caused by the wildfires with reference to the fire zones, as done in this study, instead of administrative divisions.

Table 1. Size of damaged areas according to the burn severity and fire zones in Muğla.[1]

	Burn Severity				
Wildfire Zones	**Low**	**Moderate Low**	**Moderate High**	**High**	**Total**
Mazi-Ören (1)	2784.00 (16.83)	3395.91 (20.53)	5227.23 (31.6)	5133.93 (31.04)	16541.06 (28.94)
Bodrum-Milas General (2)	173.31 (19.45)	247.68 (27.8)	376.95 (42.31)	92.89 (10.43)	890.83 (1.56)
Yatağan (3)	429.88 (39.54)	337.91 (31.08)	227.10 (20.89)	92.19 (8.48)	1087.08 (1.90)
Menteşe-Kavaklıdere (4)	3578.43 (24.42)	3314.27 (22.62)	3756.74 (25.64)	4003.61 (27.32)	14653.05 (25.64)
Marmaris (5)	3153.8 (25.72)	3609.95 (29.44)	3315.82 (27.04)	2182.02 (17.80)	12261.58 (21.45)
Köyceğiz (6)	5068.50 (47.13)	3337.04 (31.03)	1582.82 (14.72)	766.62 (7.13)	10754.98 (18.82)
Seydikemer (7)	388.80 (40.28)	293.91 (30.45)	213.26 (22.09)	69.33 (7.18)	965.31 (1.69)
Total	15576.72 (27.25)	14536.67 (25.43)	14699.92 (25.72)	12340.60 (21.59)	57153.90 (100.00)

[1] Sizes are given in hectares, the ratio of the burned area in the wildfire zone to the total fire area is given as % in parentheses.

According to the surface areas calculated by taking the topography and slope into account, the wildfire in Mazi-Ören was the wildfire with the widest damaged zone covering a surface area of 16,541.06 ha corresponding to 28.94% of the burned areas in Muğla. Menteşe-Kavaklıdere wildfire zone comes in second place with a surface area of 14,653.05 ha and it constitutes 25.64% of the burned areas. Marmaris

DOI: 10.15320/ICONARP.2022.205

wildfire zone (21.45%) with an area of 12,261.58 ha and Köyceğiz wildfire zone (18.82%) with an area of 10,754.98 ha, respectively, come after Menteşe-Kavaklıdere wildfire zone. When we examined in terms of burn severity, it was determined that the most severe fire damage was in Mazı-Ören wildfire zone.

It is important to re-emphasize that the results of scientific studies and the statistics given in the news in the media are different (see, for example, Nasery and Kalkan, 2020). However, in contrast to Nasery and Kalkan (2020), it is pleasing that on the basis of the total size of the burned areas there is no great difference between the statistical data given in the media about the Muğla wildfires, which is the subject of the study, and the results obtained in this study. For example, Nasery and Kalkan (2020) state that the results of their studies correspond to an area approximately 3-4 times larger than those mentioned in the media. The ratio between the burned area calculated in this study and the burned area given in the news in the media is only 1.16.

The size of the burned area according to the fire zones and the land cover types are given in Table 2 together with their ratio in the total burned area. According to the table, 52.37% of the residential areas damaged in the wildfires in Muğla remain in the wildfire zone in Marmaris. While 35.45% of the damaged residential areas is in the wildfire zone that started in Mazı and expanded towards Ören (Mazı-Ören wildfire zone), 12.05% of them is in the wildfire zone that started in Kavaklıdere and spread towards Menteşe district (Kavaklıdere-Menteşe wildfire zone).

In the province of Muğla, the most damaged wildfire zone of the Coniferous Forests, in which the red pines that are the product of the dominant vegetation are categorically included, is Menteşe-Kavaklıdere wildfire zone and it corresponds to 27.66% of all Coniferous Forests burned in the wildfires in Muğla. In the wildfires that are the subject of this study, 99.96% of the Broad-Leaved Forests burned in Muğla remains in Mazı-Ören wildfire zone covering almost all of the Broad-Leaved Forests burned in the wildfire. 90.66% of the burned Olive Groves are also in the Mazı-Ören wildfire zone. The wildfire zone, where agricultural areas were most damaged, is again Mazı-Ören wildfire zone. About 50% (49.41%) of the burned Mixed Forests remains in the wildfire zone of Marmaris. The results show that not only forest assets, but also agricultural areas, production areas, mining areas, urban transportation network and residential areas were damaged by the wildfires. It is seen that the ecosystem as a whole was damaged together with the components produced by human beings.

Table 2. The size of the burned areas in Muğla according to the land cover types and the wildfire zones.[2]

	Wildfire Zones							
Land Cover Types	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Beaches, dunes, sands	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.78 (100.00)	0.00 (0.00)	4.78 (0.01)
Broad-leaved forest	1218.61 (99.96)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.51 (0.04)	0.00 (0.00)	0.00 (0.00)	1219.13 (2.13)
Burnt areas	115.66 (100)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	115.66 (0.2)
Complex cultivation patterns	806.72 (63.95)	15.71 (1.25)	0.00 (0.00)	81.07 (6.43)	316.55 (25.09)	8.47 (0.67)	33.00 (2.62)	1261.53 (2.2)
Coniferous forest	6032.7 (18.37)	96.85 (0.29)	781.16 (2.38)	9078.25 (27.65)	8381.45 (25.52)	7762.33 (23.64)	705.25 (2.15)	32837.98 (57.4)
Discontinuous urban fabric	16.14 (35.45)	0.06 (0.13)	0.00 (0.00)	5.49 (12.05)	23.84 (52.37)	0.00 (0.00)	0.00 (0.00)	45.52 (0.08)
Industrial or commercial units	29.51 (100)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	29.51 (0.05)
Land principally occupied by agriculture, with significant areas of natural vegetation	1776.48 (65.59)	28.66 (1.06)	16.27 (0.6)	326.65 (12.06)	406 (14.99)	39.56 (1.46)	114.76 (4.24)	2708.38 (4.73)
Mineral extraction sites	0.00 (0.00)	0.00 (0.00)	8.09 (100)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	8.09 (0.01)
Mixed forest	246.32 (19.4)	0.00 (0.00)	0.00 (0.00)	139.6 (10.99)	627.47 (49.41)	256.62 (20.21)	0.00 (0.00)	1270.01 (2.22)
Natural grasslands	507.54 (37.78)	351.14 (26.14)	0.00 (0.00)	48.37 (3.60)	43.94 (3.27)	392.24 (29.20)	0.00 (0.00)	1343.24 (2.35)
Non-irrigated arable land	3.06 (3.24)	0.24 (0.26)	0.00 (0.00)	79.47 (84.11)	11.71 (12.39)	0.00 (0.00)	0.00 (0.00)	94.48 (0.17)
Olive groves	442.45 (90.66)	5.11 (1.05)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	40.46 (8.29)	488.02 (0.85)
Pastures	2.59 (100.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	2.59 (0.00)
Permanently irrigated land	31.77 (100.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	31.77 (0.06)
Road and rail networks and associated land	2.19 (100.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	2.19 (0.00)
Sclerophyllous vegetation	423.94 (23.1)	196.41 (10.7)	215 (11.71)	397.98 (21.68)	439.55 (23.95)	142.31 (7.75)	20.29 (1.11)	1835.49 (3.21)
Sparsely vegetated areas	96.73 (16.86)	0.00 (0.00)	0.00 (0.00)	356.45 (62.12)	118.48 (20.65)	0.00 (0.00)	2.19 (0.38)	573.85 (1.00)
Sport and leisure facilities	32.99 (63.65)	13.9 (26.82)	0.00 (0.00)	0.00 (0.00)	4.94 (9.53)	0.00 (0.00)	0.00 (0.00)	51.82 (0.09)
Transitional woodland-shrub	4755.66 (35.95)	182.74 (1.38)	66.56 (0.50)	4139.73 (31.29)	1887.15 (14.26)	2148.66 (16.24)	49.35 (0.37)	13229.86 (23.12)
Total	16541.06 (28.94)	890.83 (1.56)	1087.08 (1.90)	14653.05 (25.64)	12261.58 (21.45)	10754.98 (18.82)	965.31 (1.69)	57153.90 (100.00)

[2] Sizes are given in hectares, the ratio of the burned area in the wildfire zone to the total fire area is given as % in parentheses.

DOI: 10.15320/ICONARP.2022.205

Table 3. The size of the burned areas in Muğla according to the land cover types and the severity of the wildfire.[3]

[3] Sizes are given in hectares, the ratio of the burned area in the wildfire zone to the total fire area is given as % in parentheses. While the column named 'Total in Muğla' shows the area covered by the relevant land cover in Muğla Province, the column named '% of Total' shows the share of this area in the total land cover of Muğla Province.

	Burn Severity				Total Burned Area	% of Total	Total in Muğla
Land Cover Types	**Low**	**Mod. Low**	**Mod. High**	**High**			
Beaches, dunes, sands	4.78 (100.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.78 (0.01)	0.12	3967.98
Broad-leaved forest	152.48 (12.51)	187.46 (15.38)	235 (19.28)	644.19 (52.84)	1219.13 (2.13)	6.80	17940.3
Burnt areas	10.72 (9.27)	29.42 (25.43)	68.46 (59.19)	7.07 (6.11)	115.66 (0.20)	20.29	569.99
Complex cultivation patterns	623.64 (49.44)	421.86 (33.44)	178.6 (14.16)	37.43 (2.97)	1261.53 (2.20)	1.44	87542.76
Coniferous forest	9077.02 (27.64)	8550.56 (26.04)	7583.32 (23.09)	7627.07 (23.23)	32837.98 (57.40)	7.89	416423.46
Discontinuous urban fabric	28.39 (62.37)	10.73 (23.56)	5.63 (12.37)	0.77 (1.69)	45.52 (0.08)	0.33	13614.56
Industrial or commercial units	17.5 (59.31)	10.49 (35.55)	1.52 (5.14)	0.00 (0.00)	29.51 (0.05)	1.29	2293.3
Land principally occupied by agriculture, with significant areas of natural vegetation	830.38 (30.66)	834.4 (30.81)	715.81 (26.43)	327.79 (12.10)	2708.38 (4.73)	2.82	96000.55
Mineral extraction sites	5.67 (70.02)	1.56 (19.33)	0.86 (10.65)	0.00 (0.00)	8.09 (0.01)	0.11	7144.8
Mixed forest	339.42 (26.73)	291.86 (22.98)	233.53 (18.39)	405.2 (31.91)	1270.01 (2.22)	3.95	32140.87
Natural grasslands	369.49 (27.51)	367.96 (27.39)	463.43 (34.5)	142.36 (10.6)	1343.24 (2.35)	3.55	37838.74
Non-irrigated arable land	58.15 (61.54)	25.25 (26.73)	10.01 (10.59)	1.08 (1.14)	94.48 (0.17)	0.36	26235.33
Olive groves	150.82 (30.90)	156.51 (32.07)	126.39 (25.90)	54.3 (11.13)	488.02 (0.85)	1.57	31109.36
Pastures	1.00 (38.64)	1.53 (59.09)	0.06 (2.27)	0.00 (0.00)	2.59 (0.00)	0.15	1714.41
Permanently irrigated land	11.67 (36.74)	18.33 (57.71)	1.76 (5.56)	0.00 (0.00)	31.77 (0.06)	0.09	33820.68
Road and rail networks and associated land	1.95 (88.75)	0.25 (11.25)	0.00 (0.00)	0.00 (0.00)	2.19 (0.00)	0.69	316.55
Sclerophyllous vegetation	452.23 (24.64)	433.79 (23.63)	658.22 (35.86)	291.24 (15.87)	1835.49 (3.21)	1.29	142173.8
Sparsely vegetated areas	264.16 (46.03)	168.75 (29.41)	114.92 (20.03)	26.02 (4.53)	573.85 (1.00)	1.23	46765.02
Sport and leisure facilities	20.41 (39.38)	13.56 (26.16)	11.61 (22.41)	6.24 (12.05)	51.82 (0.09)	0.83	6234.34
Transitional woodland-shrub	3156.85 (23.86)	3012.38 (22.77)	4290.79 (32.43)	2769.84 (20.94)	13229.86 (23.12)	4.98	265575.48
Total	15576.72 (27.25)	14536.67 (25.43)	14699.92 (25.72)	12340.60 (21.59)	57153.90 (100.00)	4.31	1312022.51

In Table 3, the size of the burned areas in Muğla are given according to the land cover type and the severity of the wildfire together with their ratio to the total area for each category in Muğla. According to this table, it is seen that 57.40% of the burned areas in Muğla are Coniferous Forests. 23.23% of the burned Coniferous Forests were severely damaged, 27.64% were damaged with low severity, and a total of 49.13% were moderately-low or moderately-high damaged. When we look at the general, it was calculated that 7.89% of all Coniferous Forests in Muğla were damaged.

2.13% of the burned areas in Muğla are Broad-Leaved Forests. However, when we look at the province in general, it has been determined that 6.80% of all Broad-Leaved Forests in Muğla have been damaged. 52.84% of the burned Broad-Leaved Forests were severely damaged, 12.51% low, and a total of 34.66% moderately-low or moderately-high damaged.

Table 4. The size of the burned areas in Muğla according to type of the urban areas damaged in wildfires and the neighbourhood units (size of the areas is given in hectares).

Name of the District	Name of the Neighbourhood Unit	Discontinuous urban fabric	Industrial or commercial units	Mineral extraction sites	Road and rail networks and associated land	Sport and leisure facilities	Total Urban
Bodrum	Dereköy	0,06	0	0	0	0	0,06
	Kizilağaç	0	0	0	0	0	0
	Kumbahçe	0	0	0	0	0	0
	Mazı	1,85	0	0	0	0	1,85
	Total	1,91	0	0	0	0	1,91
Kavaklidere	Çamlibel	0	0	0	0	0	0
	Menteşe	5,49	0	0	0	0	5,49
	Total	5,49	0	0	0	0	5,49
Marmaris	Armutalan	0	0	0	0	0,31	0,31
	Hisarönü	3,82	0	0	0	0	3,82
	İçmeler	19,22	0	0	0	4,26	23,47
	Osmaniye	0	0	0	0	0,07	0,07
	Turunç	0,62	0	0	0	0	0,62
	Total	23,66	0	0	0	4,63	28,29
Milas	Beyciler	1,65	0	0	0	0	1,65
	Bozalan	8,05	0	0	0	32,67	40,72
	Gürceğiz	0	0	0	0,2	0	0,2
	Meşelik	0	0	0	0	13,9	13,9
	Türkevleri	4,58	29,51	0	1,99	0	36,09
	Total	14,29	29,51	0	2,19	46,56	92,56
Yatağan	Hisarardi	0	0	8,09	0	0	8,09
	Total	0	0	8,09	0	0	8,09
Muğla	Total	45,34	29,51	8,09	2,19	51,2	136,34

DOI: 10.15320/ICONARP.2022.205

Urban areas and settlements with livelihoods based on forest resources were also damaged by the wildfires. In Table 4, the distribution and size of the urban areas damaged by the wildfire is given according to the type of urban areas and the neighbourhood units in Muğla. When the table is analysed, it can be seen that the most damaged area regarding 'Discontinuous urban fabric' was in the wildfire zone of Marmaris with an area of 23.66 ha. The urban area that was most affected by the wildfire in Marmaris is İçmeler neighbourhood unit with an area of 19.22 ha. Milas wildfire zone suffered the most damage with an area of 46.56 ha in terms of 'Sport and leisure facilities' and with an area of 29.51 ha in terms of 'Industrial or commercial units'. The urban area that was most affected by the wildfire in Milas is Bozalan neighbourhood unit with an area of 8.05 ha.

EVALUATION

Unfortunately, approximately 8% (7.57%) of Muğla's forest assets (total of Broad-Leaved Forests, Coniferous Forests and Mixed Forests) were lost in the recent wildfires in Muğla. 2.67% of agricultural lands (total of Complex cultivation patterns, Non-irrigated arable land and Permanently irrigated land) were also damaged. In some zones, the wildfires damaged urban areas, and in some regions, rural settlements within the forest. In addition, 1.57% of the centuries-old olive fields, which have somehow become an integral part of ecological memory, have been lost. While making all these remarks, of course, we should not forget that; since burn severity is sometimes defined to include ecosystem responses, it may not yield clear results such that responses in the ecosystem include developments such as soil erosion, regeneration of vegetation, restoration of community structure, and re-emergence of fauna. Therefore, as Keeley (2009) emphasizes, it may not be possible to predict these responses with indexes or ratios developed to measure burn severity.

Indeed, although measuring the severity of burn or delimitation of the boundaries of the burned areas can be done both in the field and with remote sensing methods as also done in this study, the ability to predict the responses of the ecosystem attracts the attention of planners, geographers and managers more. Anthropogenic environmental changes can cause unexpected results by making the responses of the ecosystem unusual. Past dynamics may make it difficult to predict the resilience of the ecosystem in the face of future environmental change. In this context, the importance of ecological memory emerges again. While preserving this memory by leaving it alone for its self-regeneration has been an option until today, re-teaching the ecological memory of the ecosystem, which has started to lose its ability to renew itself by forgetting its past, seems to be another option. In this context, four major wildfire zones in Muğla (Mazi-Ören, Menteşe-Kavaklıdere, Marmaris, and Köyceğiz) offer a good test opportunity for us.

ICONARP – Volume 10, Issue 1 / Published: 30.06.2022

These regions can be left alone for a certain period of time and the potential of the ecosystem to renew itself can be examined at the end of this period. If some of the areas in those zones are outside safe operating space defined by Johnstone et al. (2016) for the forest resilience framework, as Strand et al. (2019, p. 20) argue, they may be considered as potential cases of resilience debt characterized by the "loss of an ecosystem's capacity to recover due to misalignment between disturbance regimes or post-disturbance conditions and community adaptation to fire". In this process, an adaptive resilience approach can be adopted with external support in some zones if the basic resilience response cannot be demonstrated in those zones failing to renew their memory. However, formulation of some strategies that can be followed in augmentation of socio-ecological resilience will also be an important tool for sustainable development.

It should not be forgotten that wildfires are a primary problem as they have a transformative effect on the climate and ecosystem of the region. It is important to prioritize the strategies developed for augmentation of resilience and to accelerate all actions before and after the fire. For this reason, wildfire management and action planning are urgently needed. These plans should include and spatially describe the analysis of forest conditions and trends for all forest areas, and the relationship of settlements in and around the forest with forests. Research has revealed that the characteristics, location, and physical design of settlements in and around forest areas affect both the probability and outcome of the wildfires. Therefore, the creation of forest management and spatial action plans will play an important role in building socio-ecological resilience and disaster resistance by providing spatial planning information system with an operationalization of the changes in land use (Gonzalez-Mathiesen et al., 2020). As emphasized by Thompson et al. (2016), it is also necessary to develop flexible and adaptable plans according to the changing conditions after the sources and assets that may be affected by the wildfire are identified and included in the plans. In this context, risk maps for future possible wildfires can be created by using the information obtained by remote sensing methods together with the data collected from the field (Kavlak et al., 2020; Kavlak, et al., 2021). These maps, which will be produced and updated in a systematic way, should not only be a base for the decisions taken as a component of spatial planning, but also should be evaluated in a way that creates a dynamic input to the planning process.

For the years between 2017 and 2025, within the scope of the integrated management project for Mediterranean forests with high conservation value in Turkey, fire management plans have been prepared by the Forestry Operations Directorates for different districts in the province of Muğla (see, for example, fire management plans for Köyceğiz (2017–2021), Dalaman (2021–2025), Yatağan (2020–2022), and Kavaklıdere (2019–2022) (OGM, 2022). Fire management plans aims to reduce fire risk and danger via education, awareness and training

DOI: 10.15320/ICONARP.2022.205

programs with implementation, to reduce carbon release, to protect natural habitats and the communities' life quality.

For this purpose, they predefine management zones according to physiographic factors, fire risk, land use properties and potential fire behaviour in the related project area. Although the preparation of these management plans for each district for verification of carbon, biodiversity and socio-economic benefits via monitoring, validating and reporting documents, and decision support system, is the positive side of this integrated project; we witness that many management plans in Turkey are made just to be made, the goals to be achieved are only a means instead of an aim, and the management plans that are stated to be prepared with multi-participation are helpless when real fires occur as in the summer of 2021. It is a fact that rapid identification of the fire and the ability to act very quickly before the fire grows should be a top priority.

Therefore, it is also important to develop pre-warning systems so that wildfires can be detected quickly and intervened at the right scale. Therefore, the development of new satellite-assisted risk mapping and modelling tools is urgently needed. With the visualization and modelling tools developed, it becomes important to ensure that the scope and scale of the burned areas are comprehensible (Clavet et al., 2021). In this context, monitoring and evaluation centres can be established and risk mapping and modelling processes can be carried out in these centres. Similar types of centres can be established for early warning purposes, as well as to investigate the health effects of wildfires and model the deterioration in air quality as part of resilience studies.

It should not be forgotten that the burned forest areas belong not only to the societies benefiting from that area, but also to the whole humanity, based on the fact that the ecosystem is a whole, and complementary strategies should be developed by going through a cooperation study that goes beyond the borders of the province or district without considering the administrative or political boundaries. It becomes important to ensure the re-establishment of the natural fire regime based on ecological memory by promoting the collaboration of expert from different disciplines and the restoration of ecosystem on the base of scientific knowledge, including integrated research and work in forest areas (Clavet et al., 2021). The centres mentioned above can also provide coordination regarding the participation of the society in this context.

Compared with the other studies using NBR index for the detection of burned areas such as Pepe & Parente (2018), Weirather, Zeug & Schneider (2018), and Mashhadi & Algancı (2021), this study develops a concern for the exposition of the role of NBR and similar indices for the contextualization of the relationships between the socio-ecological resilience and ecological memory, and further formulates a set of strategies to augment the resilience of the system in the face of global climate change engendering ecological memory. While Pepe & Parente (2018) solely focus on the detection of burned areas by using NBR and Normalized Difference Vegetation Index (NDVI), Mashhadi & Algancı

(2021) compare the ability of various spectral indices such as difference NBR, relative difference NBR, Relativized Burn Ratio (RBR), and difference NDVI in mapping burn severity. Interestingly, Weirather, Zeug & Schneider (2018) develop an algorithm for fully automated delineation of wildfire areas from downloading suitable data to determining the burned area via applying the difference NBR, which points to the potential of existence satellites for the establishment of a disaster alert systems regarding the wildfires.

As a matter of fact, the framework presented in this study partly overlaps with the ones available in Strand et al. (2019) and Eisenberg et al. (2019) in terms of employment of NBR in connection with the concepts of resilience and ecological memory. However, compared with these studies in this study resilience is conceptualized in a more holistic manner by marrying social dimension with the ecological one. In this regard, Eisenberg et al.'s (2019) emphasis on TEK (Traditional Ecological Knowledge) has some affinities with the framework formulated in this study in terms of assigning a practical importance to the human component of the system. As Eisenberg et al. (2019, p.10) remark, "collaboration across cultures and disciplines, which includes TEK, can help create more resilient ecosystems" and "the full historical context of TEK and traditional practices must be considered, realizing that TEK applications may need to be adapted to account for current conditions".

CONCLUSION

Mankind as a part of the ecosystem in which he lives is the actor who plays the biggest role in its change. In this context, the climate change we experience today is the result of the Anthropocene epoch. While designing and planning our living spaces, it is no longer possible for us to ignore this fact. This epoch, which is referred to as the human species, may one day begin to be covered by another layer, like other layers in geology. Climate change, triggered by anthropogenic reasons, puts humanity to a test with great disasters. In this test, there is a danger that the ecological memory of the Anthropocene period we are in is perhaps irretrievably lost. In this context, the partial damage to this memory has been exposed by using remote sensing data and GIS on the basis of the severe wildfires that took place in Muğla between 29 July and 12 August 2021. In this context, this paper can be considered as a step to question the formation of a resilience debt with reference to the framework of Johnstone et al. (2016).

As it is evident from this study, remote sensing technologies are critical for the monitoring of landcover changes. One of the areas for the application of remote sensing technologies, as illustrated in this study, is the analysis of the natural assets lost after big fires. In this study, borders of the burned areas after the wildfires are determined by using remote sensing data and GIS. Parallel to this, the damage caused by the wildfires in the built and natural environment are measured by using the standardized methods particularly developed for this purpose.

DOI: 10.15320/ICONARP.2022.205

The analysis reveals that ecological memory is at risk of being lost in quite large areas. Although some argues that ecosystems are resilient away from an ecological catastrophe, as argued in this paper, as large disturbances such as the recent big wildfires experienced in Muğla become more and more recurrent, it becomes necessary to take actions and to produce strategies for restoration of the historical ecological processes. In this respect, within the scope of the study, the general framework of the strategies to be followed in the future was drawn, and it was asserted that it is possible to compensate for the losses caused by climate change only if resilience is handled in a holistic framework. Taking the resilience of the ecosystem independent of its social and ecological dimensions may cause the same mistakes to be made. In order not to make these mistakes, it will be necessary to maintain the stability of all the tools, methods and risk policies developed and the interaction of actors from different disciplines while transferring the locally experienced wildfire results to the spatial planning context.

The real question we need to ask arises here; do we as designers and planners aspire to an ecological memory of which we are active shapers, perhaps by renewing, adapting, but not forgetting, as a part of the indifference we live in? Future resilience studies will have the opportunity to make the right choices for the ecosystem if they record the processes of loss of ecological memory, which focuses on the response of the ecosystem to all kinds of deterioration. In this context, it is clear that an effective monitoring and pre-warning system is needed. In the summer of 2021, large forest areas were burned not only in Muğla, but also in Antalya and Aydın. In terms of being an example to other provinces rich in forest assets, a monitoring centre can be established in Muğla to serve as a model to other regions in Turkey. The method used to determine the burned areas and burned intensity can be applied more frequently with the data available from different satellites for the detection of fires in places far from residential areas. Some of the recent studies such as the one conducted by Weirather, Zeug & Schneider (2018) is promising in this respect in terms of implementation of an algorithm by using open programming libraries and open satellite imagery for the fully automated workflow. In this respect, future studies may also shed some light on the employment of existing open source tools for the establishment of wildfire alert systems.

ACKNOWLEDGEMENTS

Data available from the U.S. Geological Survey; European Union, Copernicus Land Monitoring Service, European Environment Agency; Turkey's General Directorate of Mapping; and Muğla Metropolitan Municipality.

REFERENCES

Clavet, C., Topik, C., Harrell, M., Holmes, P., Healy, R., & Wear, D. (2021). Wildfire resilience funding: Building blocks for a Paradigm shift, *The Nature Conservancy*.

CORINE Land Cover (CLC), (2018). *Arazi Örtüsü Verisi*.

Congedo, L. (2021). Semi-Automatic Classification Plugin: A Python tool for the download and processing of remote sensing images in QGIS, *Journal of Open Source Software*, 6(64), 3172. https://doi.org/10.21105/joss.03172

Cumhuriyet Gazetesi (2021). *Muğla'da 66 bin hektar orman yandı*, https://www.cumhuriyet.com.tr/haber/muglada-66-bin-hektar-orman-yandi-1859130

Eisenberg, C., Anderson, C.L., Collingwood, A., Sissons, R., Dunn, C.J., Meigs, G.W., Hibbs, D.E., Murphy, S., Kuiper, S.D., Spear Chief-Morris, J., Bear, L.L., Johnston, B., & Edson, C.B. (2019). Out of the ashes: ecological resilience to extreme wildfire, prescribed burns, and indigenous burning in ecosystems. *Frontiers in Ecology and Evolution*, 436.

Gonzalez-Mathiesen, C., Ruane, S., & March, A. (2020). Integrating wildfire risk management and spatial planning – A historical review of two Australian planning systems, *International Journal of Disaster Risk Reduction*, 53, 101984.

HGK (2021). *Türkiye Mülki İdare Sınırları, Dağıtım Formatı: ESRI shp*. https://www.harita.gov.tr/urun/turkiye-mulki-idare-sinirlari/232.

Johnstone, J. F., Allen, C. D., Franklin, J. F., Frelich, L. E., Harvey, B. J., Higuera, P. E., Mack, M. C., Meentemeyer, R. K., Metz, M. R., Perry, G. LW., Schoennagel, T., & Turner, M. G. (2016). Changing disturbance regimes, ecological memory, and forest resilience, *Frontiers in Ecology and the Environment*, 14(7), 369–378.

Kavlak, M.Ö., Çabuk, S.N., & Çetin, M. (2021). Development of forest fire risk map using geographical information systems and remote sensing capabilities: Ören case, *Environmental Science and Pollution Research*, 28, 33265–33291.

Kavlak, M.Ö., Kurtipek, A., & Çabuk, S.N. (2020). Coğrafi Bilgi Sistemleri İle Orman Yangını Risk Haritası Oluşturulması: Ören Örneği, *Dirençlilik Dergisi*, 4(1), 33-54.

Keeley, J. E. (2009). Fire intensity, fire severity and burn severity: a brief review and suggested usage, *International Journal of Wildland Fire*, 18(1), 116-126.

Key, C. H., Benson, N., Ohlen, D., Howard, S. M., & Zhu, Z. (2002). *The normalized burn ratio and relationships to burn severity: ecology, remote sensing and implementation* [Paper presentation], Ninth Biennial Remote Sensing Applications Conference, Apr 8–12, San Diego, CA.

Key, C. H., & Benson, N. C. (2006). Landscape assessment (LA). In: Lutes, D. C., Keane, R. E., Caratti, J. F., Key, C. H., Benson, N. C., Sutherland, S., & Gangi, L. J. (Eds.), *FIREMON: Fire effects monitoring and inventory system*, General Technical Report, RMRS-GTR-164-CD, Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station, p. 1-55, 164.

Llorens, R., Sobrino, J. A., Fernández, C., Fernández-Alonso, J. M., & Vega, J. A. (2021). A methodology to estimate forest fires burned areas and burn severity degrees using Sentinel-2 data. Application to the October 2017 fires in the Iberian Peninsula, *International Journal of Applied Earth Observation and Geoinformation*, 95, 102243.

Lutes, D. C., Keane, R. E., Caratti, J. F., Key, C. H., Benson, N. C., Sutherland, S., & Gangi, L. J. (2006). *FIREMON: Fire Effects Monitoring and Inventory System. General Technical Report*, RMRS-GTR-164-CD, Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. https://www.fs.fed.us/rm/pubs/rmrs_gtr164.pdf

Mashhadi, N., & Algancı, U. (2021). Determination of forest burn scar and burn severity from free satellite images: a comparative evaluation of spectral

DOI: 10.15320/ICONARP.2022.205

indices and machine learning classifiers. *International Journal of Environment and Geoinformatics*, 8(4), 488-497.

McWethy, D.B., Schoennagel, T., Higuera, P.E., Krawchuk, M., Harvey, B. J., Metcalf, E. C., Schultz, C., Miller, C., Metcalf, A. L., Buma, B., Virapongse, A., Kulig, J. C., Stedman, R. C., Ratajczak, Z., Nelson, C. R., & Kolden, C. (2019). Rethinking resilience to wildfire, *Nature Sustainability,* 2 (2019): 797–804. https://doi.org/10.1038/s41893-019-0353-8

NASA SRTM (2013). *Shuttle Radar Topography Mission (SRTM) GL 1*.

Nasery, S., & Kalkan K. (2020). Burn Area Detection and Burn Severity Assessment Using Sentinel 2 MSI Data: The Case of Karabağlar District, İzmir/Turkey, *Turkish Journal of Geosciences*, 1(2), 72-77.

OGM (2021). *Yüzdelik Olarak İllere Göre Orman Varlığı*. https://web.ogm.gov.tr/Documents/Orman_Varligi_Dosyalari/Yuzdelik-Illere-Gore-Orman-Varligi.pdf.

OGM (2022). *Yangın Yönetim Planları/Muğla OBM*. https://web.ogm.gov.tr/ekutuphane/Dokumanlar/Yangın Yönetim Planları/Muğla OBM.

Pepe, M., & Parente, C. (2018). Burned area recognition by change detection analysis using images derived from Sentinel-2 satellite: The case study of Sorrento Peninsula, Italy. *Journal of Applied Engineering Science*, 16(2), 225-232.

Peterson, G.D. (2002). Contagious disturbance, ecological memory, and the emergence of landscape pattern. *Ecosystems*, 5(4), 329-338.

Polat, N., Kaya, Y. (2021). Çok Bantlı Uydu Görüntüleriyle Orman Yangınlarında Hasar Tespiti, *Bartın Orman Fakültesi Dergisi*, 23(1), 172-181.

QGIS (2021). *Quantum GIS*. https://qgis.org/

Roy, D. P., Huang, H., Boschetti, L., Giglio, L., Yan, L., Zhang, H. H., & Li, Z. (2019). Landsat-8 and Sentinel-2 burned area mapping-A combined sensor multi-temporal change detection approach. *Remote Sensing of Environment*, 231, 111254.

SAGA (2021). *System for Automated Geoscientific Analyses.* http://www.saga-gis.org/en/index.html

Saulino, L., Rita, A., Migliozzi, A., Maffei, C., Allevato, E., Garonna, A. P., & Saracino, A. (2020). Detecting burn severity across mediterranean forest types by coupling medium-spatial resolution satellite imagery and field data, *Remote Sensing*, 12(4), 741.

Selles, O. A., Rissman, A. R. (2020). Content analysis of resilience in forestfire science and management, *Land Use Policy*, 94, 104483, 1-12. https://doi.org/10.1016/j.landusepol.2020.104483

Sobrino, J. A., Llorens, R., Fernández, C., Fernández-Alonso, J. M., & Vega, J. A. (2019). Relationship between forest fires severity measured in situ and through remotely sensed spectral indices, *Forests*, 10(5), 457.

Sözcü Gazetesi (2021) *Muğla'da orman yangınlarının bilançosu ortaya çıktı*. https://www.sozcu.com.tr/2021/gundem/muglada-orman-yanginlarinin-bilancosu-ortaya-cikti-6584017/

Strand, E.K., Satterberg, K.L., Hudak, A.T., Byrne, J., Khalyani, A.H., & Smith, A. (2019). Does burn severity affect plant community diversity and composition in mixed conifer forests of the United States Intermountain West one decade post fire? *Fire Ecology*, 15(1), 1-22.

Sümer, Ö., Akin, A., & Tekin, A. (2020). Antropojen ve Antroposen kavramlarının tarihsel gelişimine yerbilimsel bir bakış, *Türkiye Jeoloji Bülteni*, 63(1), 1-20.

Thompson, M.P., Bowden, P., Brough, A., Scott, J.H., Gilbertson-Day, J., Taylor, A., Anderson, J., & Haas, J.R. (2016). Application of Wildfire Risk Assessment

Results to Wildfire Response Planning in the Southern Sierra Nevada, California, USA, *Forests*, 7, 64. doi:10.3390/f7030064

Türkeş, M., & Altan, G. (2013). İklimsel değişimlerin ve orman yanginlarinin Muğla Yöresi'ndeki doğal çevre, doğa koruma alanlari ve biyotaya etkilerinin bir ekolojik biyocoğrafya çözümlemesi, *Ege Coğrafya Dergisi*, 22/2, 57-76, İzmir.

Walker, R.B, Coop, J.D, Downing, W.M, Krawchuk, M.A, Malone, S.L, & Meigs, G.W. (2019). How much forest persists through fire? High-resolution mapping of tree cover to characterize the abundance and spatial pattern of fire refugia across mosaics of burn severity. *Forests*, 10(9), 782.

Weirather, M., Zeug, G., & Schneider, T. (2018). Automated Delineation of Wildfire Areas Using Sentinel-2 Satellite Imagery. *GI_Forum 2018*, 6, 251-262.

Resume

Burak Beyhan is a Professor at the Department of City and Regional Planning, Muğla Sıtkı Koçman University. He received his degrees (B.CP., M.RP., and Ph.D.) in the Department of City and Regional Planning at METU, in Ankara, Turkey. His main research interests are in the areas of urban and regional planning, regional development and innovation systems, geographic information systems (GIS) in planning, and urban and planning history in Turkey.

Feray Koca is an Associate Professor at the Department of City and Regional Planning, Muğla Sıtkı Koçman University. She received her B.Sc. degree in the Department of Landscape Architecture, Ankara University, and M.UD., and Ph.D. degrees in the Department of City and Regional Planning at METU, in Ankara, Turkey. Her main research interests are in the areas of urban design and planning, urban morphology, environmental policies, management and issues, traditional settlements and settlement pattern in Turkey.

DOI: 10.15320/ICONARP.2022.205