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Innovative Action for Forest Fire Prevention in Kythira Island, Greece, through Mobilization and Cooperation of the Population: Methodology and Challenges

Gavriil Xanthopoulos [1,*], Miltiadis Athanasiou [2], Alexia Nikiforaki [2], Konstantinos Kaoukis [1], Georgios Mantakas [1], Panagiotis Xanthopoulos [1], Charalampos Papoutsakis [1], Aikaterini Christopoulou [1], Stavros Sofronas [1], Miltos Gletsos [2] and Vassiliki Varela [1]

[1] Hellenic Agricultural Organization "Demeter", Institute of Mediterranean & Forest Ecosystems, Terma Alkmanos, 11528 Athens, Greece; kako@fria.gr (K.K.); mage@fria.gr (G.M.); panosxant@hotmail.com (P.X.); xarispap11@hotmail.gr (C.P.); aikatchr@gmail.com (A.C.); sofronass@gmail.com (S.S.); vvarela@otenet.gr (V.V.)

[2] Hellenic Society for the Protection of Nature, Nikis 20, 10557 Athens, Greece; info@m-athanasiou.gr (M.A.); alexia.nikiforaki@gmail.com (A.N.); mgletsos@eepf.gr (M.G.)

* Correspondence: gxnrtc@fria.gr; Tel.: +30-210-779-3142

Abstract: The island of Kythira in Greece suffered a major forest fire in 2017 that burned 8.91% of its total area and revealed many challenges regarding fire management. Following that, the Hellenic Society for the Protection of Nature joined forces with the Institute of Mediterranean and Forest Ecosystems in a project aiming to improve fire prevention there through mobilization and cooperation of the population. This paper describes the methodology and the results. The latter include an in-depth analysis of fire statistics for the island, development of a forest fuels map, and prevention planning for selected settlements based on fire modeling and on an assessment of the vulnerability of 610 structures, carried out with the contribution of groups of volunteers. Emphasis was placed on informing locals, including students, through talks and workshops, on how to prevent forest fires and prepare their homes and themselves for such an event, and on mobilizing them to carry out fuel management and forest rehabilitation work. In the final section of the paper, the challenges that the two partners faced and the project achievements and shortcomings are presented and discussed, leading to conclusions that can be useful for similar efforts in other places in Greece and elsewhere.

Keywords: fire prevention; fire statistics; forest fires; public participation

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1. Introduction

Forest fires are a natural process of most forest ecosystems around the world but at the same time, due to their environmental, social, and economic impacts, they constitute a significant natural hazard, a problem that societies have to face. In the last two decades many scientific studies have affirmed that there is a worsening trend regarding this problem [1–3]. Whereas, Doer and Santin [4] questioned the widely held perception, both in the media and scientific papers, that wildfires are an accelerating problem due to increasing fire occurrence, severity and resulting losses, multiple wildfire disasters in the last few years have provided clear evidence that the wildfire problem is globally on the rise. Extreme fires that exceed by far the capacity of even the most competent firefighting mechanisms, often causing huge damage and multiple fatalities in addition to vast burned areas, tend to become commonplace [5–8] while, in parallel, significant fires have started to occur in unusual places, such as countries in the northern latitudes [9–11]. Such large fires do not only have devastating effects on vegetation, soil erosion, flooding [12] water quality [13], carbon sequestration [14], etc., but they also upset the economy, function and psychology of local societies [15,16].

The inability of firefighting mechanisms to control fires that exceed certain levels of fire behavior, as summarized by Tedim et al. [17], leads, as a rule, to efforts aiming to increase these threshold levels through better organization, faster response, more resources, and adoption of technological advances, alas at an ever increasing cost. This approach, merely directed to fire extinction without due attention to prevention, can be described by the metaphor of the "firefighting trap". This term, in business, describes a "quick-fix" management strategy, which focuses on fixing rather than preventing problems, often resulting in unintended negative consequences [18]. In the realm of forest fire management, such a strategy can initially appear successful as it is likely to reduce damage in the short term, but in the long term it fails to address the roots of the increasing wildfire potential [19] resulting in the so-called "fire paradox" [20,21]. This problem has been documented clearly and current scientific thinking calls for shifting the focus from fire suppression to mitigation, prevention, and preparation, as such a policy is more likely to reduce the negative socioeconomic and ecological effects of fire than the current, largely one-dimensional, focus on fire exclusion [22].

An emphasis on forest fire prevention is the alternative approach for mitigating the problem of forest fires. According to the FAO's Wildland Fire Management Terminology, fire prevention includes "all measures in fire management, fuel management, forest management, forest utilization and concerning the land users and the general public, including law enforcement, that may result in the prevention of outbreak of fires or the reduction of fire severity and spread". Fire prevention is a term widely found in the international scientific literature, reflecting its importance. Most of the research efforts and publications are devoted to technical aspects such as fire risk prediction and mapping, fire detection, etc. Regarding forest fuel management, scientific studies have clearly shown the influence of the condition of forests and their fuels (after fuel treatment or previous fires) on fire behavior and severity [23,24], so forest and fuel management is usually part of fire prevention programs. In wildland–urban interface areas in particular, properly implemented fuel treatments can play a significant role in protecting assets, reducing fire severity and increasing forest resilience [25].

In addition to fuel management, fire prevention aims at effective reduction of fire starts, improved safety, and mitigation of damage, especially when a fire escapes initial attack and reaches a wildland–urban interface area. All these prevention elements are closely tied to people, their knowledge and their attitudes. Since, in most places in Europe [26] and around the world [27] the vast majority of fires are caused by humans, many fire prevention programs include a strong component focused on people [28,29]. The research work devoted to this effort is probably less than that on technical fire prevention issues, but there are still numerous efforts to analyze behaviors at individual and community levels [30–38]. On the other hand, there are many examples of applied efforts that aim to educate, motivate and guide people to contribute to fire prevention, by reducing fire ignitions, at personal and community scales. Information about them is quite often not in the form of scientific publications but in the form of "grey literature" (articles, reports, essays, handbooks, field guides, internet sites, etc.). Examples are the training manual published by the International Tropical Timber Organization (ITTO) on "Forest fire prevention for Community" [39]; the report of Hesseln and Ergibi (2017) [40,41] on the "FireSmart-ForestWise" program in Canada; the "Wildfire Risk to Communities" website created by the USDA Forest Service under the direction of Congress [42]; the "Firewise USA" site of the National Fire Protection Association (NFPA) [43]; and the "Community Fireguard" program of the CFA in Australia [44].

The Mediterranean countries of Europe are among those where forest fires have become a major problem. Fire suppression receives a lot of attention and has become the focus of heated debates, especially during and after difficult fire seasons, and this happens with increasing frequency due to aggravation of the conditions that lead to major fire disasters. In general, there is a consensus that in regions with Mediterranean-type climate the currently prevailing emphasis of fire management on suppression is doomed to fail, so

a shift towards prevention, and preparation is both logical and pragmatic. Accordingly, policy and expenditures should be balanced better between suppression and mitigation of the negative socio-ecological impacts of fire [18,22,45].

Aggressive forest fire behavior in recent years, whatever the reason, is a major problem for fire managers. In Greece, however, the forest fire management reality includes an additional challenge: there are more than 200 inhabited islands, some of them at considerable distance from the mainland and the abundant firefighting resources there. Thus, in many cases fire suppression cannot be as effective as on the mainland, at least for as long as it takes for reinforcements to arrive. Thus, fires that escape initial attack have great potential to grow and threaten settlements and infrastructures. Obviously, the only option for such islands, other than building-up a disproportional and costly fire suppression capacity that will be idle most of the time, is to maximize the effort for fire prevention and effective initial attack.

The work described here focused exactly on developing and testing an approach for fire prevention on one such Greek island, based to a significant extent on the innovative involvement of local volunteers. The methodology, outcomes, and challenges that were faced are presented in this paper.

2. Materials and Methods

The work focused on the island of Kythira, which lies south of Peloponnese, Greece, has an area of 277.28 km^2 and a population of 3973 people according to the most recent (2011) census. The number of people on the island increases steeply in the summer with the return of Kythirians from Athens and the foreign countries to which they have emigrated, and with the addition of numerous tourists. Kithira is an example of a remote island with relatively poor connection to the mainland by boat or by air. Not surprisingly, it has a long history of significant forest fires. In 2017, it suffered a major fire that burned a large part of the island. It started on 4 August, next to the hospital of Kythira near the village of Aroniadika (location "Pitsinades") and burned 2471 ha (8.91% of the island) (Figure 1), after changing its main spread direction many times and threatening villages, homesteads, and the historic monastery of Panagia Mirtidiotissa. A large part of the fire perimeter stopped at the sea. The fire was officially declared as extinguished 18 days later.

The fire of 2017 revealed many weaknesses regarding fire management on the island. In the years that followed, the local authorities and other state agencies started an effort to improve prevention and suppression. Initially they focused on flood protection works, and then they tried to improve prevention infrastructures such as water tanks, fire hydrants, forest roads etc. On the other hand, the Hellenic Society for the Protection of Nature (HSPN), the oldest national environmental NGO in Greece, joined forces with the Institute of Mediterranean and Forest Ecosystems (IMFE) of the Hellenic Agricultural Organization "Demeter" for a project aiming at fire prevention improvement, but with a different emphasis compared to that of the authorities: they mainly focused on mobilization of the citizens. They were inspired to a large extend by the prevention examples with public involvement mentioned above, realizing, however, that as people and conditions are different, the local context must be taken into consideration, innovating where needed.

Forest fire prevention refers to all the actions carried out before the start of a fire that aim to reduce the probability of a fire starting, the potential for quick growth and aggressive behavior if a fire starts, and the potential for damage in case of a fire. Furthermore, it includes the existence of effective fire detection and good planning for a quick response and effective initial attack. Being less visible than suppression, fire prevention is often neglected.

Fire prevention is quite broad and complex. It has a significant planning component and includes physical works such as forest road maintenance, securing water sources (e.g., constructing water tanks, water ponds, fire hydrants, etc.), forest and fuels management, as well as a host of activities that focus on people. This is because most fires are human-caused, and the safety of people is a top priority of forest fire management. All these three components must be present in order to achieve effective and efficient prevention.

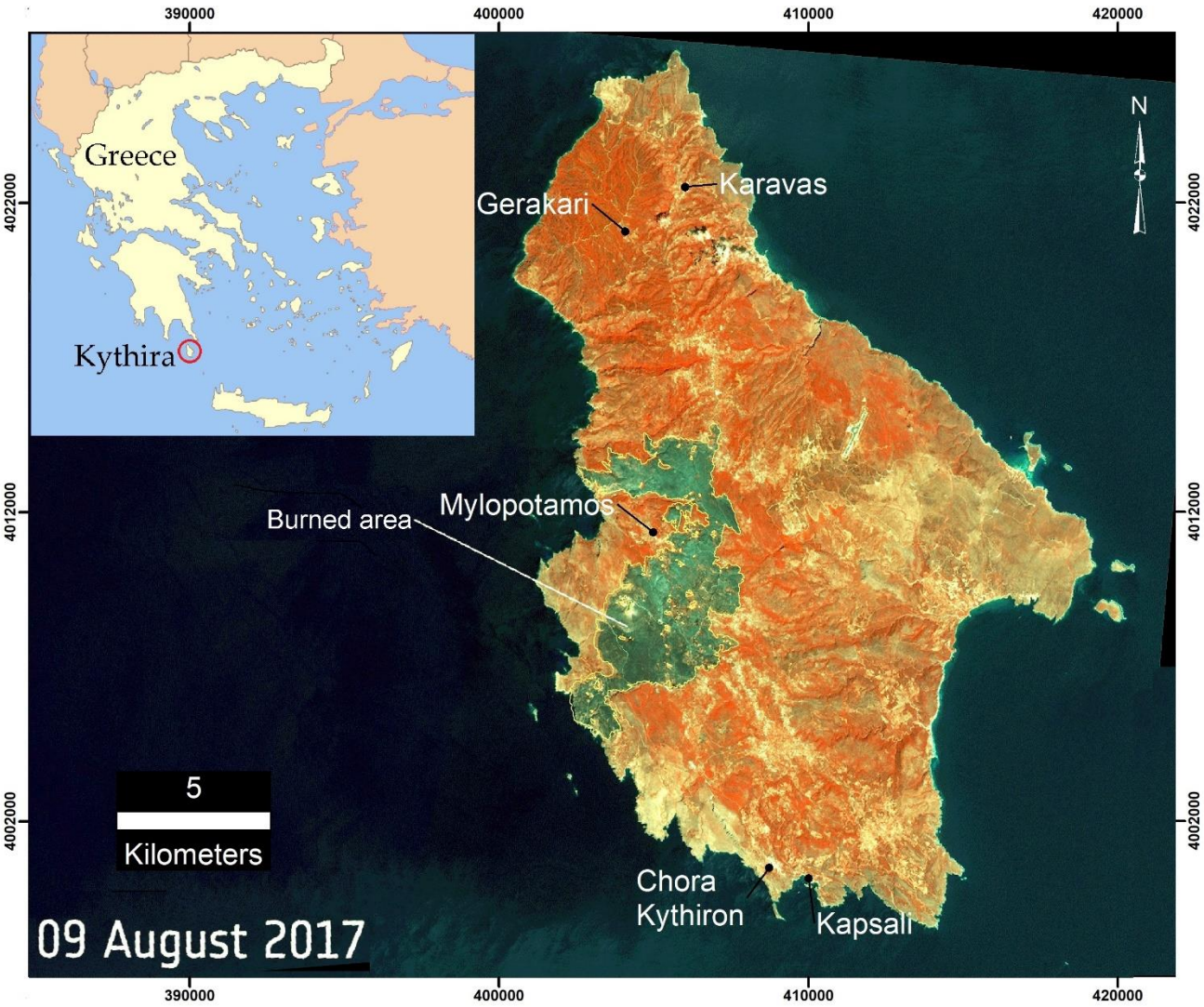


Figure 1. A map of Greece showing the location of Kythira, in-laid in an annotated false color composite image of the island, captured by the Copernicus Sentinel-2 satellite pair, immediately after the 4 August 2017 fire. The scar of the fire is clearly visible. (Image source: The European Space Agency https://www.esa.int/ESA_Multimedia/Images/2017/08/Kythira_wildfires, accessed on 1 December 2021).

In the frame of the project, as there was no capacity (mandate, manpower, funding) to perform physical works, it was decided to focus on the planning component and to work with the people. Physical works require much more funding and they are handled anyway by the local authorities that receive funding from the state budget through the General Secretariat for Civil Protection. Thus, the objective was to fill the existing gap, by relating scientific knowledge to and working with people, innovatively blending the two components where possible, in order to reduce the number of fires and burned area, and to mitigate damages. In doing so, it was intended to demonstrate, making prudent use of the small project budget, the efficiency that can be achieved through this approach.

The methods used to pursue the aims of the project followed two directions. The first, was an effort to understand and analyze the fire problem and the conditions (e.g., fuels, topography) on the island, in support of fire prevention and presuppression planning. The second included all the efforts that aimed to mobilize the people on the island for fire prevention. Most of the work concentrated in the area of three main settlements, as was planned at project inception, but there were also activities that covered the whole

island. The three settlements are (a) Karavas and Gerakari in the north of the island, (b) Mylopotamos at the center, and (c) Chora Kythiron and Kapsali in the south (Figure 1).

More specifically, the methods focusing on understanding and analyzing the fire problem consisted of:

- Documentation of the fire problem in Kythera, based on an analysis of Forest Service and Fire Service forest fires statistical records for the last 20 years and a search for reports on forest fires in available newspaper records for the last 50 years. This was followed by an examination of topography and long-term meteorological data, resulting in identification of the conditions (place and time) associated with very high fire hazard.
- A field campaign for identification and documentation of the forest vegetation and fuel situations on the island, followed by assignment of the corresponding fuel models to each such situation. The fuel model description follows the concepts used in the US Forest Service fire behavior prediction and simulation systems (BehavePlus [46,47], Farsite [48], Flammap [49]) where a fuel model is used as input representing fuels in Rothermel's mathematical model for predicting fire spread in wildland fuels [50]. The fuel models used have been developed specifically for Greece [51,52] and have undergone testing against real-world fires [53]. With the help of photo keys [51], in a manner similar to [54], the vegetation conditions were matched to fuel models. Where a good match between fuel situations and existing fuel models could not be found, a new fuel model was created for Kythira following the methodology proposed by Xanthopoulos and Manasi [55]. This was the case of evergreen shrubs with a height up to 80 cm. The fuel models were used with BehavePlus, with weather and slope conditions typical for the island, in order to estimate potential fire behavior.
- Development, for the first time in Kythira, of a forest fuels map, based on the identification of forest fuel situations above. The map was created through manual interpretation/digitization, in a GIS environment, utilizing georeferenced field photos of fuel situations for training the photo-interpreters. A recent forest map of the Forest Service was used as basis, with further distinction and delineation of fuel situations based on Google Earth images. For example, photointerpretation allowed distinction of the vegetation category of evergreen shrubs into tall, low and very low shrubs, corresponding to different fuel models. The representativeness of the fuel map was then evaluated in the field.
- Simulation of the spread of the 4 August 2017 fire using the G-FMIS fire spread simulator [56] after developing a good documentation of its real evolution through mass media reports, testimonies of witnesses, photos, and videos. Inputs to the simulation were the fuels map, the digital elevation model (DEM) for Kythira, and the meteorological conditions. The objective was to examine the possibility of achieving a realistic simulation before using G-FMIS for further simulations.
- Carry out fire spread simulations starting at selected high-risk locations in the vicinity of the three selected settlements, using the G-FMIS fire spread simulator. The simulations were based on the fuels map, the DEM, and plausible average worst fire weather scenarios.
- Development, using GIS, of a map of safe separation distance (SSD) between the potential flame and the firefighters, based on vegetation height, slope and wind [57,58].
- Evaluation of the risk of destruction of nearly all the buildings (N = 610) in the three settlements through a structure-by-structure assessment, with the help of small teams of volunteers. The volunteers were given a standard form which they had to fill for each structure. The form lists in classes the main elements affecting its risk in case of fire (properties and distance of surrounding vegetation, topography, characteristics of the building that affect its vulnerability, ease of access, fire protection infrastructure, etc.). The volunteers were first trained how to fill the forms. Then they were given a satellite image from Google Earth of the settlement they had to visit with the structures numbered in sequence. They visited each structure, took photographs and filled in

the corresponding form. A scoring system was used to assess the risk of destruction of the structure. The result was double checked by the fire experts of the research partners through the photos and with the help of Google Earth. Additionally, a field visit allowed verification of the results for a sample of structures. The final assessment for each structure was then entered in a risk assessment form to be distributed to the structure owner. The assessment form informed the owner of the risk due to vegetation and due to the vulnerability of structure elements, as well as of the overall risk. It also offered recommendations on what needs to be changed to improve safety. Additionally, the form included a warning in case the owner would decide to stay and defend, recommending early evacuation in case of high-risk, hard-to-defend structures. These forms were distributed personally to each owner through the volunteers. The owners were also asked to fill in a short questionnaire with their opinion about the assessment and on their willingness to act to improve the safety of their structure.

- A confidential map showing the structures, color-coded according to their risk, was provided to the Fire Service. Further mapping identified areas of exceptionally high-risk, as a result of high SSD, concentration of vulnerable structures, and poor road access, where special planning is needed and early evacuation is advised. These maps were also delivered to the authorities.

The contribution of the volunteers to the assessment of the risk of structures also formed the link between the direct scientific input of the forest fire experts and the work that aimed to mobilize the citizens. This work included:

- A series of talks by the fire experts of the two partners to inhabitants of Kythira on fire prevention, at all three settlements, explaining the problem of forest fires, introducing the concept and the content of fire prevention and urging for mobilization and cooperation of the people. It was in the first meetings of this series that the teams of volunteers were formed.
- A series of talks to elementary and high school students, aiming to make them aware of the issue of forest fires, providing them with practical information on prevention and with simple and effective take-home messages. Each of these events was tailored to the corresponding student level and employed appropriate techniques with the help of professional environmental educators of the HSPN.
- Voluntary field activities by volunteers and students including reforestation of selected sites, and understory fuel management in selected stands along roads. The extent of both activities was limited as they are quite demanding. Their main objective was to foster a voluntary spirit.
- Production of two informative videos (a) on making a home that is situated near forest vegetation safe (12 min) and (b) on how a citizen should react if threatened by a fire in the vicinity (30 min). The videos were distributed to local media, were made available to the local authorities and to the volunteers and were also uploaded to YouTube. A third video was also produced, documenting all the activities of the project.
- Production of a four-page brochure with practical information on fire prevention specifically for Kythira.
- A series of articles about the forest fire problem in Kythera and its mitigation published in the local press and in the tri-monthly magazine of the HSPN.
- A series of interviews with local radio stations on the subject of fire prevention involving fire experts of the research partners' teams.

3. Results

3.1. Results of Past Fires Documentation and Analysis

The results of the scientific effort were multiple, useful and inspiring for the authorities and the people. The search for forest fire records in the newspapers and the analysis of the fire statistics revealed the patterns of fire on the island. For example, a fire on 8 August 1971 that burned about 2000 ha and threatened the monastery of Panagia Mirtidiotissa, was much like the 2017 fire that started on 4 August and burned 2471 ha in roughly the same

area, also threatening the monastery. This finding provided an excellent example in the talks to the people, showing that in a Mediterranean environment like that of Kythira, fire is a recurring phenomenon, so serious preparation regarding the safety of their homes and their personal readiness is well justified. Also, the search of the records showed that on a number of occasions fires trapped tourists in small, secluded beaches that dot the perimeter of the island having, due to the steep topography, only one access road. Evacuation by boats offered a solution in those cases but current planning should take this probability into consideration.

Regarding the fire statistics records, a total of 228 fires were recorded in the 2000–2019 period. Only six of them (2.6%) became very large (>100 ha), but they contributed 88.7% of the 6135.46 ha that burned in this period (Figure 2).

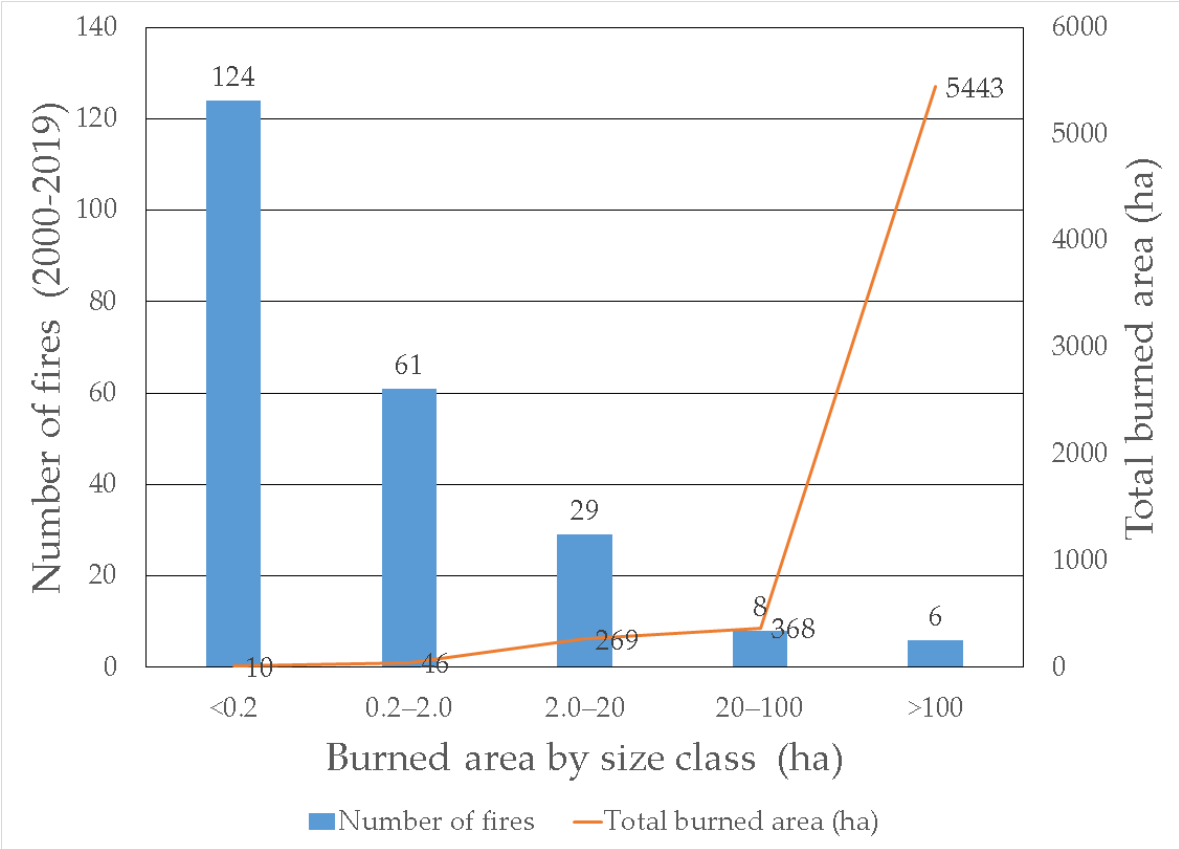


Figure 2. The number of fires in Kythira by size class and their contribution to the total burned area for the 2000–2019 period.

Regarding the burned area on Kythira, the total of 6135.46 ha, represents 22.07% of the whole area of the island. This percentage is much larger than the 6.13% figure for the whole country, for the same period, and is an indication of increased difficulty and/or shortcomings in the management of the fire problem on the island.

On the average, 19 fires occurred per each calendar month within the 2000–2019 period, having a fairly even distribution. May is an exception with only six fires in these 20 years, while July with 28 fires and August with 27, as expected, are the months with the highest fire frequency. However, the distribution is very different regarding large fires and burned area. With the exception of a 1804 ha fire that occurred on 23 June 2000, all the other large fires (>100 ha) occurred in August. Most of the large fires occurred in years characterized by a challenging fire season.

Regarding firefighting, Table 1 lists the nine fires, out of the total of 228 which received aerial firefighting. With the exception of the lightning-caused fire of Agia Moni, which

received initial attack drops by two light PZL M-18 Dromader aircraft and only burned a few square meters, all the other fires burned for more than 10 h. Also, strong aerial support was only made available for fires that grew to more than 10 ha. To a large extent, this illustrates the effect of the distance of Kythera from the central bases of aerial resources and supports the argument that effective prevention and strong initial attack are highly important for the island.

Table 1. The nine forest fires on Kythira, in the 2000–2019 period that received aerial firefighting support.

Area	Date	Fire Start	Fire Duration (Hours)	Burned Area (ha)	Helicopters	CL-415 or CL-215	PZL M-18	Aerial Resources (All)
Agia Moni	12 September 2018	14:50	5.5	0	0	0	2	2
Vrisi Mitaton	12 March 2018	11:14	10.9	0.4	0	2	0	2
Venergianika	9 July 2017	15:24	29.8	2.5	1	0	0	1
Friligianika	3 July 2016	09:44	28.9	2.6	0	2	0	2
Mantala	24 August 2019	19:29	84.7	12.0	3	2	0	5
Gerakari	9 November 2017	12:34	90.9	20.0	0	2	0	2
Aginara	9 October 2012	09:22	84.6	116.5	0	6	0	6
Melidoni	1 August 2013	15:23	101.1	251.0	1	2	0	3
Pitsinades	4 August 2017	10:55	411.1	2471.0	3	5	0	8

Examination of the prevailing wind conditions showed that in the summer months the wind blows mainly from a NE direction, falling under the well known "meltemi" wind pattern that is prevalent in the summer season in the Aegean sea, in Greece. However, as Kythira is located between the Aegean sea to the east and the Ionian sea to the west, westerly winds from the Ionian are the second most common. Whereas in the islands of the Aegean firefighters may count on the NE meltemi wind for their fire suppression planning, in Kythera, especially for larger fires lasting for many days, planning should consider the increased probability for wind shifts, as happened in the case of the large fire of 4 August 2017.

3.2. Forest Fuels Map

The forest fuel map that was developed for Kythera is shown in Figure 3. It is the first time such a tool became available for the island, and it can be very useful both for fire prevention planning and fire suppression. Table 2, provides a simple general correspondence of the fuel types with fuel models.

The limited areas of tall forest, cover 1.31% of the island and consist mainly of *Pinus halepensis* with an occasional mix of Eucalypt (*Eucalyptus globulus*). These forests are the result of earlier reforestation efforts. In some very limited spots there are only pine needles on the ground, and the bottom of the crown starts at 1–1.5 m. The height of the trees generally varies between 8–15 m and below their crown, as a rule, there is a thick evergreen shrub understory (Figure 4). The evergreen shrubs layer, both in the understory and in the open, consists of such species as *Arbutus unedo*, *Quercus coccifera*, *Pistacia lentiscus*, *Erica manipuliflora*, *Erica arborea*, *Juniperus phoenicea*, *Ceratonia siliqua*, *Genista acanthoclada*, etc. In all cases, in the summer, under even medium fire weather conditions, fires in the tall pine forests with such understory, burn as active crown fires, with the spread rate dictated by the shrub component. Thus, in Table 2, the tall forest fuel type was assigned to the "tall maquis" fuel model for fire modelling purposes. The values of the parameters of the fuel models are listed in Table 3 [51,52].

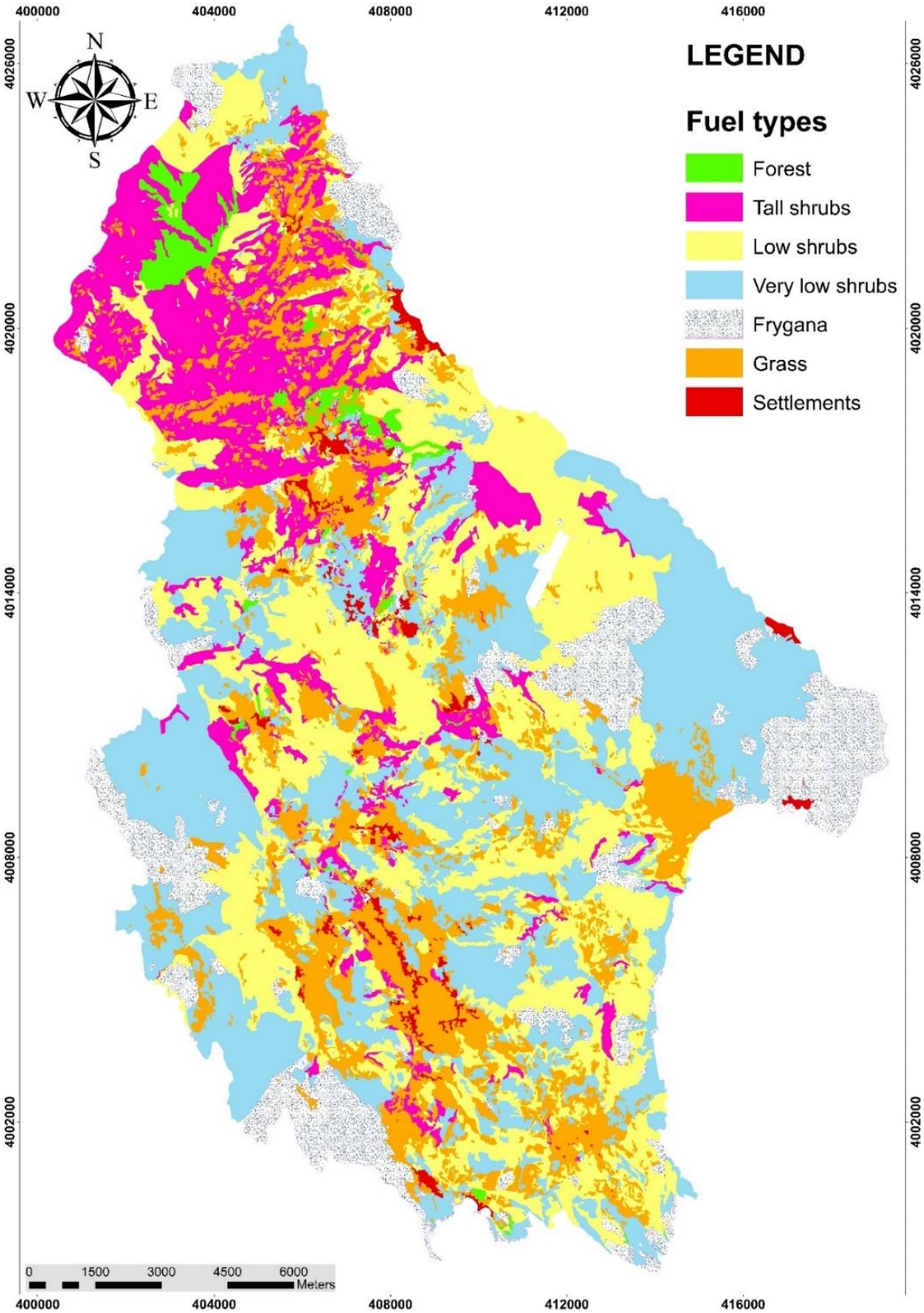


Figure 3. The forest fuel types map of Kythira.

Table 2. Correspondence of fuel types on Kythera with fuel models for Greece [51,52]. A custom fuel model was developed for Kythira for better representation of the "Very low shrubs (avg. height < 0.8 m)" fuel situation.

Fuel Type	Fuel Model
Tall forest (usually with shrub understory)	Tall maquis
Tall shrubs (avg. height > 1.5 m)	Tall maquis
Low shrubs (avg. height 0.8–1.5 m)	Low maquis
Very low shrubs (avg. height < 0.8 m)	Custom fuel model for Kythira
Phrygana (avg. height < 0.5 m)	Phrygana (*Sarcopoterium spinosum*)
Agricultural cultivations (grass)	Mediterranean grassland
Settlements	No burn area

Figure 4. An example of a *Pinus halepensis* stand with evergreen shrub understory near the settlement of Gerakari.

Table 3. The values of the fuel model parameters used in Kythira, adapted from [51,52].

Parameter / Fuel Model	Low Maquis (Model I)	Tall Maquis (Model II)	Phrygana (*Sarcopoterium Spinosum*) (Model V)	Mediterranean Grassland (Model VI)	Very Low Shrubs at Kythera
Dead fuel load <0.63 cm (1-Hr) (Mton/Ha)	9.91	17.88	3.50	4.82	3.06
Dead fuel load 0.63–2.54 cm (10-Hr) (Mton/Ha)	6.80	13.30	1.02	0.49	0.86
Dead fuel load 2.54–7.62 cm (100-Hr) (Mton/Ha)	3.60	8.5	0.28	0.00	0.00
Live Herbaceous fuel load (Mton/Ha)	0.00	0.00	0.00	0.00	0.00
Live Woody fuel load <0.63 cm (Mton/Ha)	7.70	10.60	0.85	0.00	9.79
Surface-area-to-volume-ratio for 1-Hr dead fuels (1/cm)	55	55	65	78	55

Table 3. *Cont.*

Parameter / Fuel Model	Low Maquis (Model I)	Tall Maquis (Model II)	Phrygana (*Sarcopoterium Spinosum*) (Model V)	Mediterranean Grassland (Model VI)	Very Low Shrubs at Kythera
Surface-area-to-volume-ratio for live herblaceous fuels (1/cm)	-	-	-	-	-
Surface-area-to-volume-ratio for live woody fuels (1/cm)	55	55	65	-	55
Fuel Bed Depth (cm)	102.19	203.58	40.00	27.53	39.34
Fuel moisture content of extinction (%)	34	34	20	14	33
Heat Content (J/G)	20,000	20,000	19,054	18,600	19,050

3.3. Testing of Fire Spread Simulation in Kythira

As mentioned earlier, the evolution of the 4 August 2017 fire was documented in detail mainly through photos and videos of known locations and time, offered by local volunteers, discussions with Fire Service personnel and other locals, and finally through mass media reports which had devoted significant live reporting time. The meteorological conditions were obtained from the local weather station. Using the G-FMIS fire spread simulator [56], which has been extensively tested in Greece, the fuel map, and the DEM of Kythira, the spread of the fire was simulated. The wind flow over the terrain was taken into consideration through the NUATMOS model (Ross et al., 1988) which is embedded in G-FMIS. The results of the simulation are shown in Figure 5. They were assessed as quite realistic.

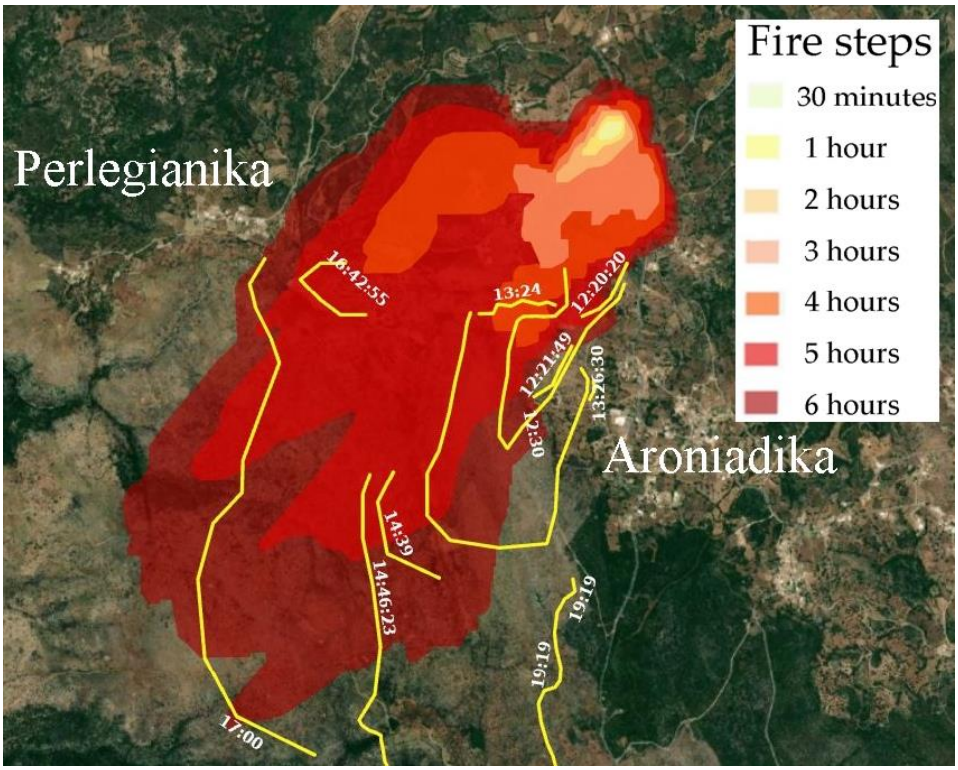


Figure 5. Comparison of the actual evolution of the perimeter of the fire of 4 August 2017 in Kythira (Pitsinades fire), which started at 10:55 am, with the simulated growth of the perimeter at regular intervals with the G-FMIS system, using the actual meteorological conditions of that day and the fuel map of Figure 3.

3.4. Simulations of Probable Fires in the Vicinity of the Three Settlements at Kythira

Having established the capability for reliable fire modelling on the island, the fuels map was then used in conjunction with a fire weather scenario similar to the difficult conditions during the 2017 fire, for fire spread simulations with G-FMIS, in the vicinity of the three selected settlements on the island. Two wind direction scenarios were used according to the prevailing directions during the summer (NE and W). For each case, an ignition point was selected, such that with the prevailing wind direction the fire would hit the corresponding settlement. An example is shown in Figure 6. The simulations allowed the fire management authorities to understand the challenge they may be called to face under such fire scenarios. Additionally, they helped to illustrate to the people of the particular settlements that there can be conditions under which, within a short time, the firefighting resources of the island will be overwhelmed and will not be able to control the blaze or defend all the houses. This made many people take the fire prevention messages more seriously and realize that they need to prepare their homes for such an event.

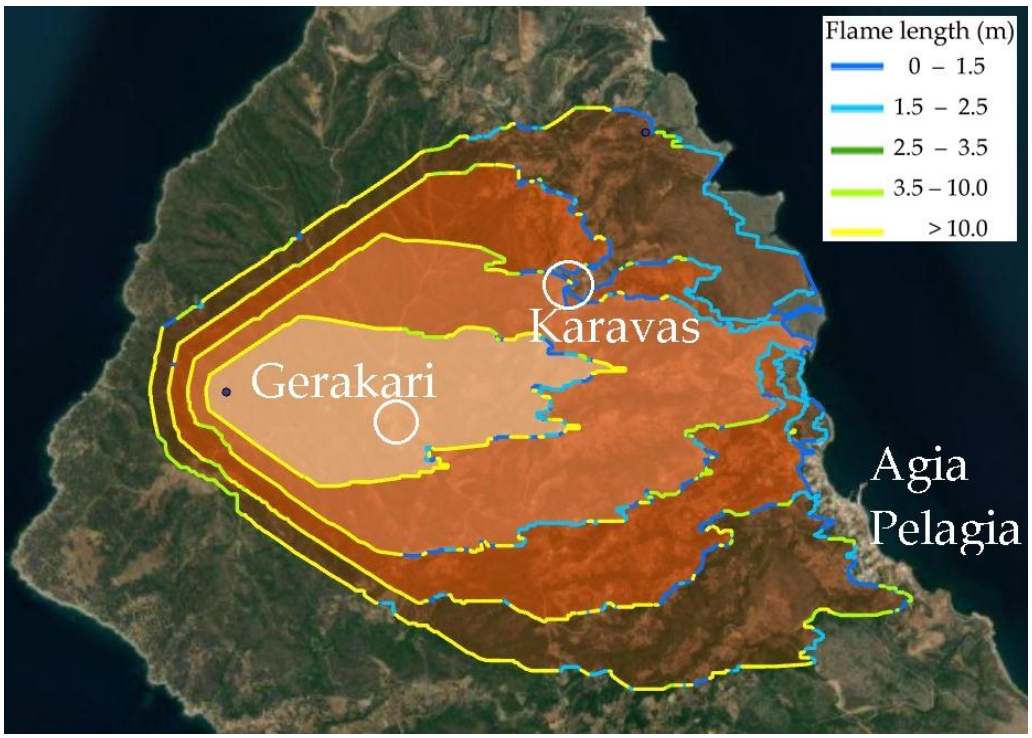


Figure 6. A fire spread simulation example, using the G-FMIS fire simulation system, in the north part of Kythira (Karavas and Gerakari settlement) under a west wind, showing fire perimeter growth (in four hourly steps) and flame length (m) along the perimeter color-coded in five classes.

3.5. Assessment of the Risk of Destruction of Structures with the Help of Volunteers

The work of the volunteers on assessment of the risk of destruction of each structure in the three settlements (Figure 7) resulted in 704 completed forms. Finally, 610 structures were evaluated. The remaining 94 were abandoned or collapsing, or, in a few cases, there were missing data in the forms. The evaluation of the risk of each structure through a scoring system was further reviewed, adjusted and verified in the field by the fire experts of the two partners. Subsequently, a form was prepared for each structure to be delivered to the homeowners. This semi-automatically created form included an assessment of destruction risk in cases of fire but also offered guidance on needed safety improvements and suggestions on how to react in cases of fire (Figure 8).

Figure 7. A team of volunteers filling risk assessment data forms for homes in one of the settlements in Kythira.

Προστασία της Φύσης
ΕΛΛΗΝΙΚΗ ΕΤΑΙΡΙΑ ΠΡΟΣΤΑΣΙΑΣ ΤΗΣ ΦΥΣΗΣ

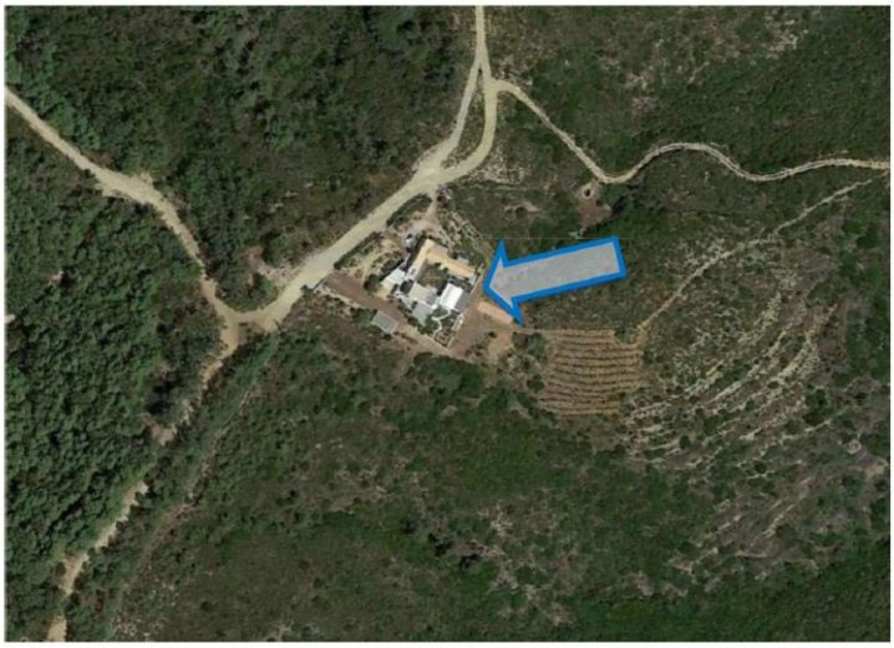
Ινστιτούτο Μεσογειακών Δασικών Οικοσυστημάτων
ΕΛΛΗΝΙΚΟΣ ΓΕΩΡΓΙΚΟΣ ΟΡΓΑΝΙΣΜΟΣ - ΔΗΜΗΤΡΑ

ΠΡΑΣΙΝΟ ΤΑΜΕΙΟ

Έργο: «Καινοτόμα δράση για την πρόληψη των δασικών πυρκαγιών στα Κύθηρα με την κινητοποίηση και συνεργασία του πληθυσμού, πιλοτικά σε 3 οικισμούς» ΜΕΤΡΟ: «ΚΑΙΝΟΤΟΜΕΣ ΔΡΑΣΕΙΣ ΜΕ ΤΟΥΣ ΠΟΛΙΤΕΣ», ΧΡΗΜΑΤΟΔΟΤΙΚΟ ΠΡΟΓΡΑΜΜΑ: «ΦΥΣΙΚΟ ΠΕΡΙΒΑΛΛΟΝ & ΚΑΙΝΟΤΟΜΕΣ ΠΕΡΙΒΑΛΛΟΝΤΙΚΕΣ ΔΡΑΣΕΙΣ 2018»

Evaluation of the risk of destruction of a house due to a forest fire

House - Questionnaire Number:	XXX
Owner:	Unknown
Housing Location:	Gerakari
Phone number:	Unknown



Index A- Hazard resulting from the characteristics of the forest fire	Very High
Index T - Vulnerability of the residence	Average
Index K – Integrated risk assessment for the structure	**High**

Figure 8. *Cont.*

The risk of destruction of the house by a forest fire is High.

The surrounding vegetation is a factor of especially high risk to your house. You should contact the local Forest Service or the Municipality immediately in order to get help regarding prevention measures you could take. You have to clean the area around the house from dead burnable material to mitigate the danger from a possible forest fire. Grasses have to be cut and removed, shrubs must be thinned out and lower tree branches have to be pruned to a minimum of 2 meters from the ground.

The vulnerability of your residence from a probable forest fire is average. There are some changes and improvements that should be made to the most vulnerable elements, which are a source of weakness. To keep the safety of your residence at a high level, make sure that in the case of a forest fire you will shut off the windows and doors in time, to prevent smoke and burning embers from entering. If you cannot evacuate in time, in an organized way and safely, you will need to remain in the house so that you will not be exposed to smoke and flames.

You should know that if you decide to stay and protect your residence, you should have received training by the Fire Service and should be using the proper equipment for personal protection and firefighting.

If there are obstructions to the access of the firefighting forces to your home, they may delay their efforts and decrease their ability to fight the fire.

A wooden pergola can be an element that increases the risk in case of a forest fire, especially if combined with straw, water reed or cloth to provide more shade. To decrease the risk, you may paint it with fire-resistant varnish, and may use a fire-resistant cloth.

Fences made with coniferous vegetation (Thuja, Leyland, Cypress) are easy to ignite even from lighted embers and burn with great intensity. Fences made with broad leaved plants (such as *Nerium oleander*) and even better with climbing species (ivy, honeysuckle) offer protection instead, especially if they are watered regularly.

The above assessment is a short and non-exhaustive way of assessing the potential risk of destruction of a house by a forest fire. The method of calculation covers the most important factors of this risk and gives a fairly representative assessment, in order to offer a first assessment to the owner as to whether his home is in danger and what could be the possible changes to improve the situation. By using the corresponding application on the IMFE website (http://www.fria.gr/prolipsi/files/Assessment-Form.html) the result of possible changes that the owner will make in reducing the risk can be evaluated.

ATTENTION: As IMFE, is not directly involved in the recording of data, but also due to the existence of many unpredictable parameters during the passage of a fire, IMFE cannot be held responsible for any failures. Citizens should be informed and follow the instructions of the official bodies in case of fire. More information on fire prevention for citizens is available at: http://www.fria.gr/prolipsi/, and about the project at https://tinyurl.com/kainotoma-kythira

Figure 8. An example of the form with assessment of the risk of a particular house, to be handed personally to its owner.

In addition to the assessment of individual structures for the benefit of the owners, the results were also shown on a map that was made available (confidentially) to the authorities (Figure 9). The combination of fire behavior analysis with the structure vulnerability map allows better protection of the settlements both at the fire prevention planning stage and when trying to defend them in case of fire.

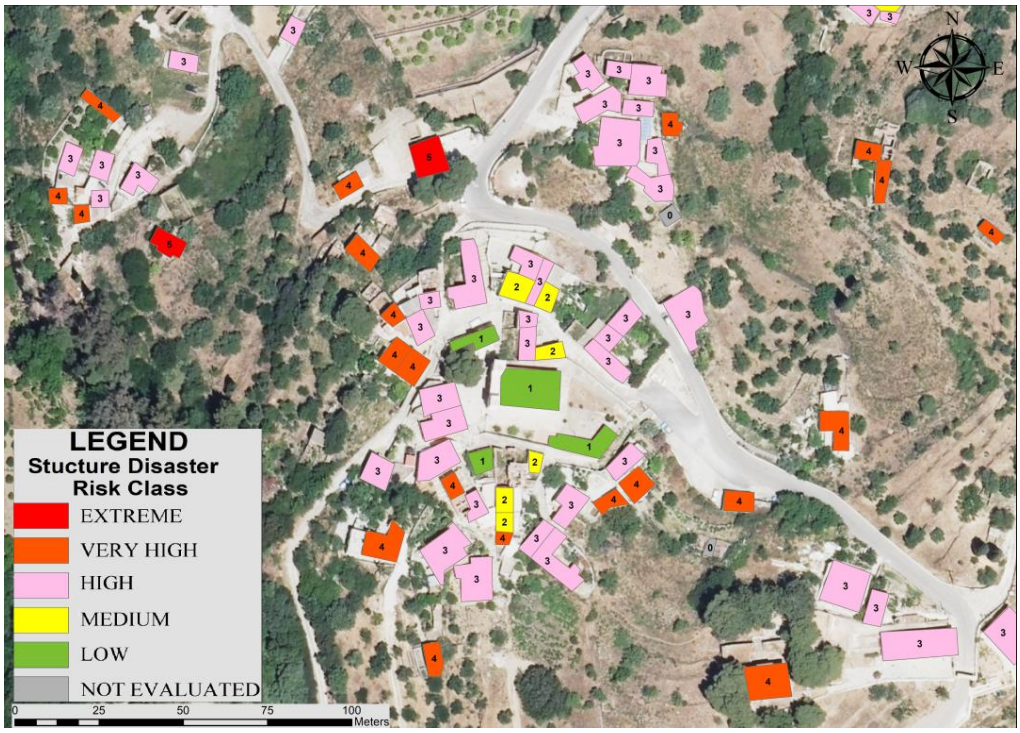


Figure 9. A small example of the structure disaster risk map that was created for use by the authorities at Kythira island. Each structure is color-coded in one of five risk classes (low to extreme).

3.6. Owner Opinion about Their Home's Assessment and Their Willingness to Act

The homeowners, who received the forms about the fire risk of their structures, were asked through a short questionnaire to state their opinion about the assessment they received and to express their willingness to act to improve the safety of their structure. A few more questions of interest were also asked. This follow-up was also carried out by volunteers. A total of 230 valid questionnaires were collected.

The questionnaire results showed that the fire of 2017 had changed the viewpoint of many homeowners regarding the potential risk the fires represent for their home. Before the fire, 23% declared that they did not perceive any threat, while 25% were slightly worried. After the fire, the corresponding percentages dropped to 8% and 14%, respectively. The majority of the homeowners (71%) declared that they had not attended any of the educational activities of the project, providing a feeling about the reach of the project to the people on the island.

The perception the homeowners had about the potential fire risk for their home before they received the form, proved to be quite different than the assessment they received (Figure 10). However, they agreed overwhelmingly with the assessment after studying the form (Figure 11). Furthermore, the majority of them stated that they will implement the suggestions in the form completely (48%) or partially (38%) (Figure 12).

3.7. Map of Firefighter Safe Separation Distance (SSD)

Using vegetation height, slope and wind as input variables, the firefighter safe separation distance [57,58] was calculated and mapped using ArcGIS (Figure 13). The map reveals areas, mainly in the north of Kythira, where ground firefighting of the fire front would be impossible in case of a fully developed summer fire and can contribute greatly in presuppression planning.

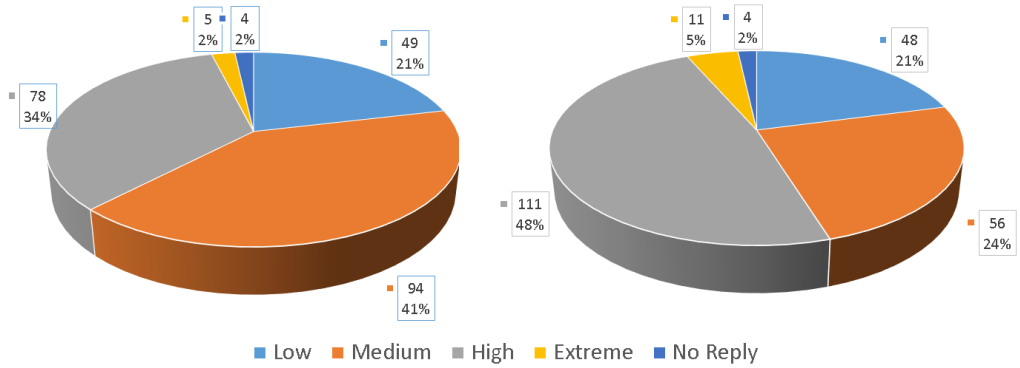


Figure 10. Perception of the homeowners of the potential risk for their home in case of forest fire before they received the form (**left**), and the risk assessment through the form (**right**).

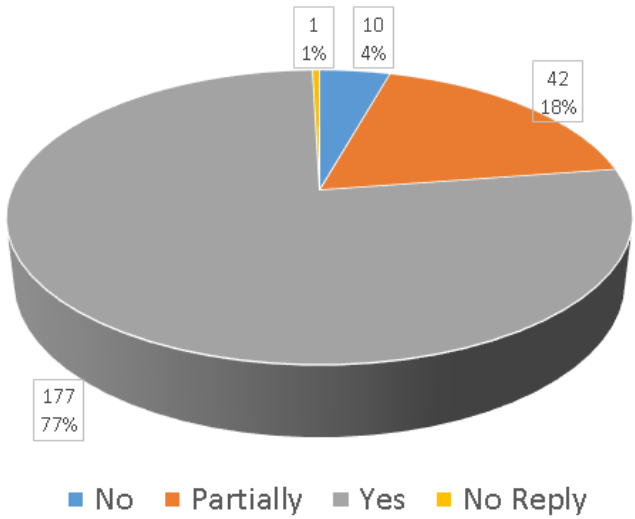


Figure 11. Degree of agreement of the homeowners with the assessment they received about the risk to their home in case of fire.

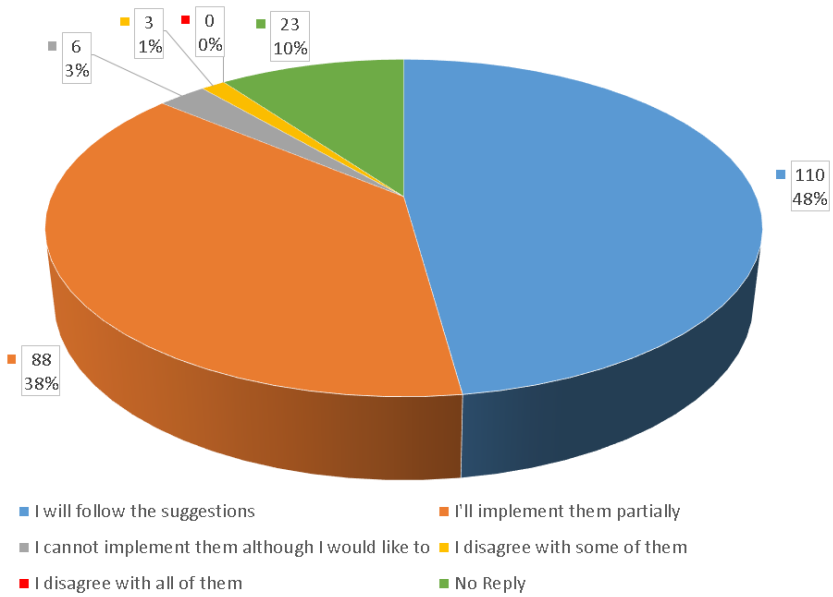


Figure 12. Stated willingness of homeowners to implement risk mitigation measures for their homes, according to the suggestions provided to them through the risk assessment forms.

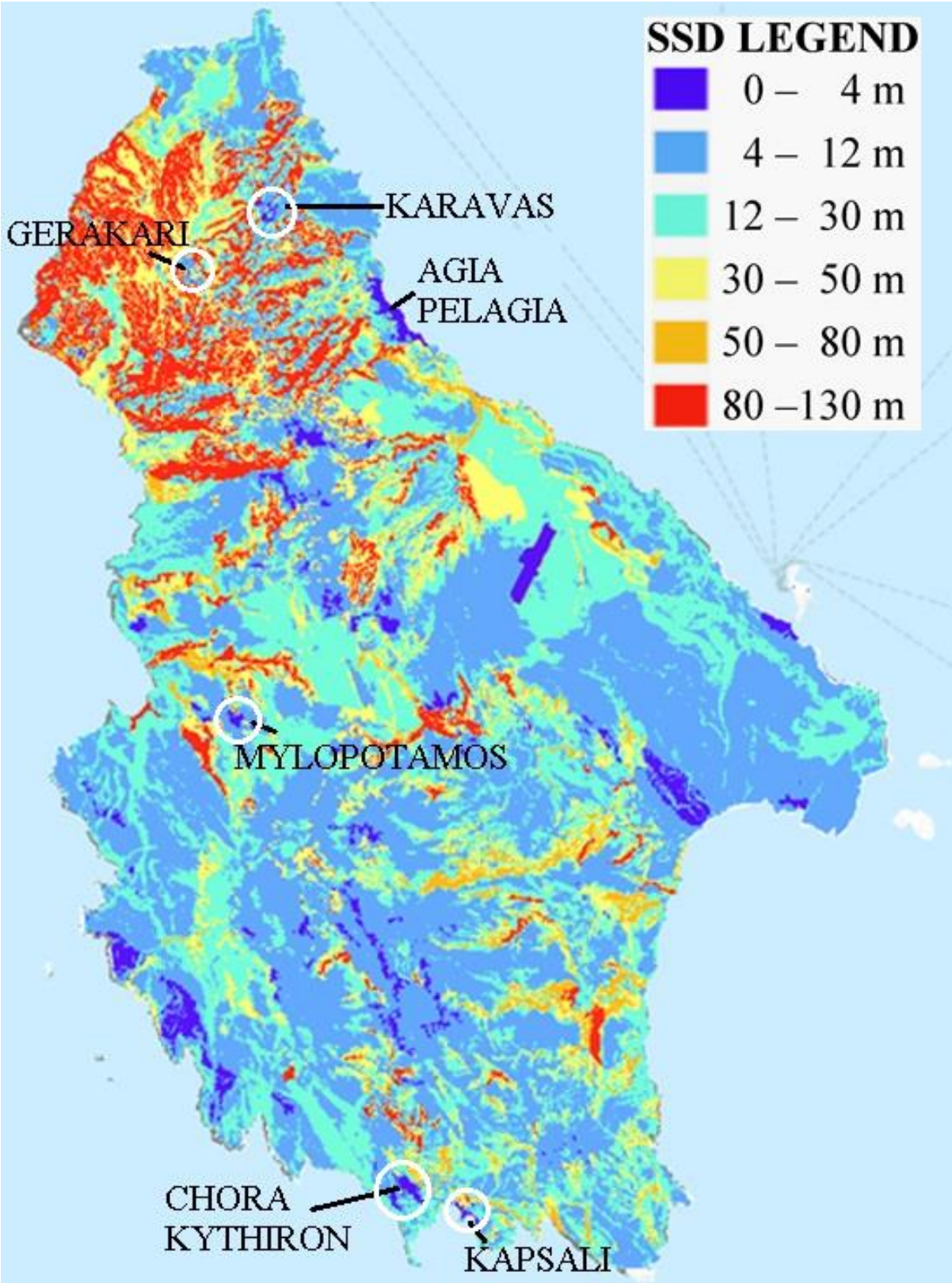


Figure 13. The firefighter safe separation distance (SSD) in meters mapped across Kythira in six classes.

Focusing on the settlements under consideration and combining the SSD map, the house risk assessments and the ease of access, the areas of great concern where there can

be grave danger to the people in case of fire became evident. These were pointed out in detailed maps that were provided to the authorities (Figure 14).

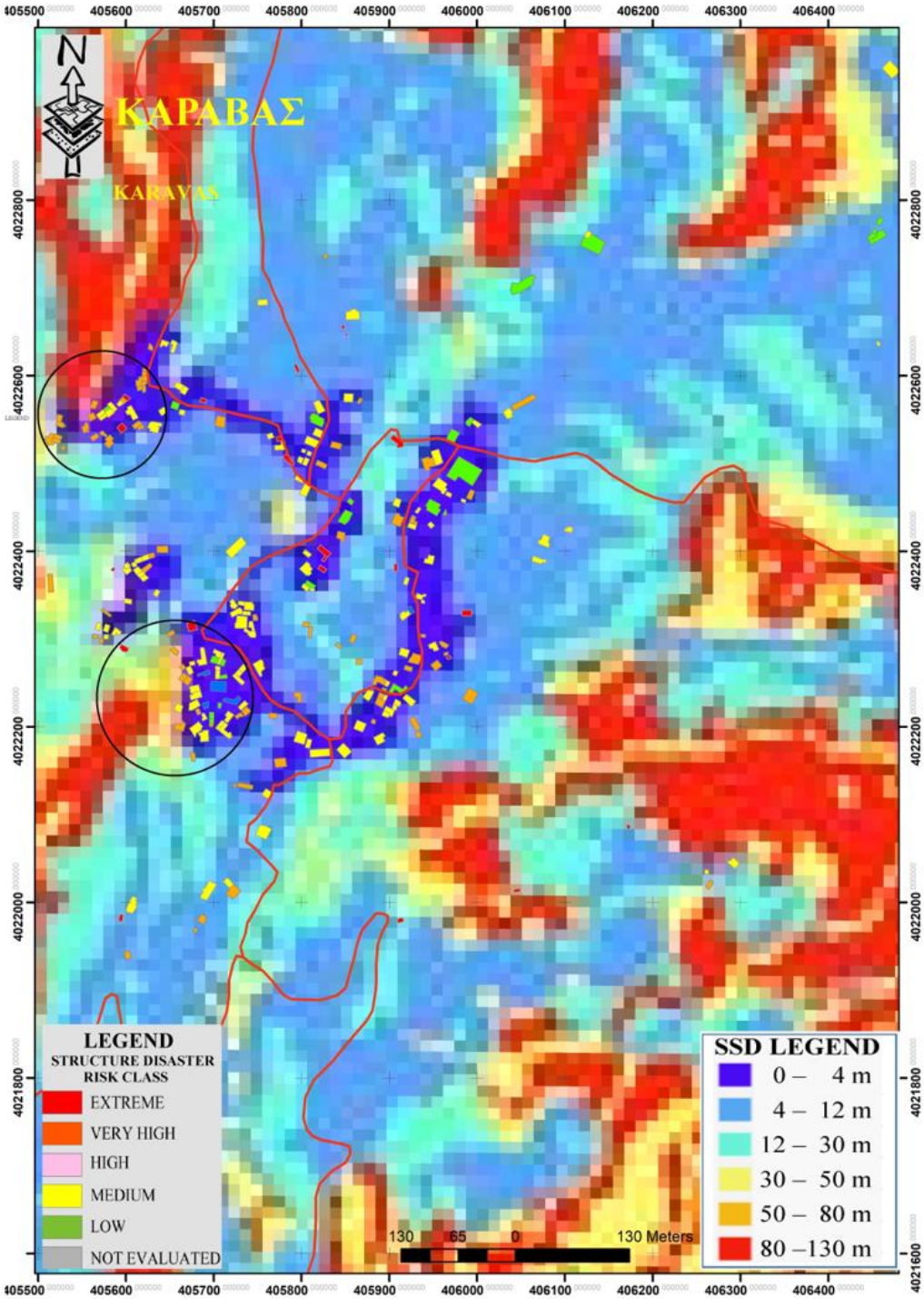


Figure 14. A detailed map of homes in Karavas, color coded according to their risk class, and the SSD in the vicinity of the settlement. Two groups of homes that can be at extreme risk in case of a fire arriving from the west, are indicated with black circles.

3.8. Mobilization and Cooperation of the Population

Early in the timeline of the project it was deemed necessary to explain to the population the concept and breadth of fire prevention and its importance for the island of Kythira. After initial contacts it became clear that there had to be separate workshops organized in

the north, center and south of the island, because people would not be willing to travel. Thus, it was decided to carry the workshops in small places that they felt comfortable with (Figure 15). The first round of workshops that consisted of talks on fire prevention followed by discussion achieved its objective because it stirred interest and permitted the formation of teams of volunteers. Based on the realization that an intense quick-spreading fire under high fire danger could easily overwhelm the limited firefighting resources of the island, exposing settlements to risk of destruction before the arrival of reinforcements, it was demonstrated that improvement of the safety of homes had to be one of the priorities. Thus, it was agreed with the volunteers that one of their main contributions could be to help assess the risk of destruction of individual homes in the three settlements, a task they successfully completed as explained earlier.

Figure 15. Examples of two workshops in a tavern in Mylopotamos (**left**) and in a small gallery in Chora Kythiron (**right**), in 2019.

Additional meetings were carried out later in the life of the project to act as refreshers of the key prevention messages and as opportunities for information dissemination on the overall progress. However, with the onset of the COVID-19 pandemic in March 2020, the task became much more challenging. There were periods of many months during which it was not possible to travel to Kythira, and when this was allowed, the meetings had to be carried out in open spaces such as a village square, a restaurant or even an open-space bar (Figure 16). Additionally, many people who would normally come to Kythira in the summer (e.g., Kythirians who emigrated abroad many years ago but maintain a home on the island, or those who live in Athens) were not able to make it in the summer of 2020. These difficulties made it necessary to extend the project by 1 year, to the end of September 2021, in order to carry out activities in the summer of 2021.

Figure 16. Examples of two workshops in open spaces, in 2021.

In parallel to the workshops for the grown-ups, talks to the students of the only high school on the island and the two elementary schools aimed to convey the message of fire prevention to the new generation. The talks to the high school students were delivered by the fire experts of the partners and were followed by discussions. On the other hand, specialized environmental educators of the HSPN, employing not only talks but also interactive games in the schoolyard, delivered the message to the younger pupils

(Figure 17). These activities were particularly successful as these young people, having witnessed the disastrous fire of 2017, were more than eager to pick-up the fire prevention message and to spread the word. They were also given fire prevention leaflets to carry home, which they were happy to do.

Figure 17. Examples of talks to high-school students (**left**) and activities in the schoolyard with pupils (**right**).

The pool of volunteers and of enthusiastic students was also given the opportunity to act in the frame of forest fire prevention and post-fire rehabilitation participating in two activities organized mainly through the efforts of HSPN. The adults treated understory fuels in a *Pinus halepensis* stand along a highly used road, while the students worked on reforestation in a burned area (Figure 18).

Figure 18. Two of the activities that aimed to foster voluntary spirit; fuel treatment (**left**) and reforestation (**right**).

Regarding dissemination of prevention messages at massive scale, the teams of the two partners prepared a four-page brochure that was distributed to the population at the start of the fire season of 2021. Additionally, they prepared two informative fire prevention videos which were uploaded to YouTube at the following links: (a) Making a home safe for the case of a forest fire (https://youtu.be/HmZx1yWtuYI, accessed on 1 December 2021), and (b) How to react in case of fire (https://youtu.be/zS5JN8Kd48A, accessed on 1 December 2021). Following uploading, the links were publicized through various channels (mailing lists of professionals, relevant internet sites, social media, etc.).

The four-page fire prevention brochure that was produced specifically for Kythira was received very positively during the meetings held in June 2021, resulting in the need for a second printing. However, at that time, the local entrepreneurs also suggested that there is a need for creation of a similar brochure in foreign languages, to be distributed through hotel owners and other professionals to the numerous tourists visiting the island every summer.

4. Discussion

All the activities described earlier have certainly contributed towards the main objective of the project, to improve forest fire prevention in Kythira. This, rather than introduction of technical advancements in fuel mapping or fire modelling, was the emphasis of the work. The element of innovation was mostly in the way the technical work blended with the involvement of the people in order to achieve better fire prevention efficiently. Working

with the citizens on fire prevention, of course, is not new. There exist numerous efforts around the world, such as the FIREWISE USA program of NFPA, which has a long history, recognizes the value of voluntary action and provides numerous resources to people in order to make their communities and homes safe from wildfire [35]. Community participation is sought and is a longstanding practice, not only in the USA, but also in Canada and in Australia [32,36]. However, people's attitudes are very different between countries and continents and the same is true for their social structures and their natural and built environment [59,60]. For example, while in Greece less than 10% of adults participate in volunteer activities, in the European Union, in countries such as The Netherlands, Sweden and Austria this percentage is over 40% [61]. As a result, the examples of community involvement cannot be simply copied.

In Greece, organized volunteerism historically has not been strong, while people are very eager to help on a personal basis when the need arises, if they are motivated appropriately. In Kythira, motivation was tried, innovatively, with the involvement and cooperation of volunteers with the fire experts, and their ultimate contribution to fire prevention planning on the island, putting an emphasis on the idea of providing examples. As the other people watched the volunteer teams become organized and trained, and then visit structures in the three settlements completing forms, they became curious. Participation in the talks and the activities increased. Many owners of restaurants and coffee shops offered their space and infrastructure for free, initially indoors, and after the onset of the COVID-19 epidemic, in the space outside their shops, providing a further positive example. The elementary and high-school teachers on the island also contributed enthusiastically, facilitating the work of the environmental educators of the HSPN. The delivery of the risk assessment forms by the volunteers to the structure owners, on a personal basis, further increased awareness and provided motivation by example. The percentages of agreement regarding the risk evaluation of the homes and the willingness to take measures for home risk mitigation were quite high and impressed the researchers who did not expect this from the aging and generally laid-back population of the island. The result is in line with the findings of McFarlane et al. [62] that threat assessment has the greatest effect on mitigation by homeowners, followed by perceived effectiveness of mitigation. The risk assessment forms that were given personally to the homeowners in Kithira offered both these elements.

It is worth noting that the change in the perception of homeowners regarding the risk to their homes and their willingness to act is not independent of the large 2017 fire that they experienced and is in line with the findings of [63]. Actually, the project made use of the "window of opportunity", regarding population mobilization after a disastrous wildfire, that was reported by McGee et al. [63]. The impression made by the 2017 fire was even stronger and longer-lasting for the pupils and students. Even in 2021, four years later, the memory persisted and the attention of the students to the prevention messages remained very high.

Community engagement and participation, as a rule, is initiated and managed by official agencies [36]. In Greece, with some notable exceptions, this approach has not worked well so far. The alternative developed in this study provides an effective approach, which is tailored to the profile and mentality of the population. The interaction of experts with the citizens, the two-way communication, and the feeling that they were all participants in a common effort were keys to success. On the other hand, a sophisticated approach based on volunteered geographic information (VGI), using social media and technologies such as web-based mapping, as tried in [36], would likely be unsuccessful in Kythira.

The technical information offered to the authorities, including fire occurrence analysis, forest fuel mapping, fire spread simulations, and fire damage potential (both from the side of the fire and the vulnerability of structures), can help greatly regarding fire prevention planning and setting fire suppression priorities. On the other hand, all the activities with the citizens, with the addition of articles, videos, and local radio interviews, make it likely that a significant percentage of the population of Kythira has been exposed to the concept and have learned about the practicalities of forest fire prevention.

Assessment of the effectiveness of the activities of the project on the outcomes of fire prevention, especially as manifested by burned area, the occurrence of a large fire, or fire caused damage, cannot be done with confidence in a short period of time. Nevertheless, there were four fires recorded in 2019 and nine fires in 2020. These numbers are lower than the 11.5 fires that occur on average per year. Furthermore, the total burned area was 16.1 ha in 2019, and 25.5 ha in 2020, which is much lower than the average yearly burned area of 306.8 ha for the 2000–2019 period. Also, there were no reported injuries to people or damage to homes.

As seen in the fire statistics of the island, large fire events happen sporadically, usually in fire seasons that are difficult for the whole country. This may reflect the high fire danger conditions that lead to aggressive fires starting, which quickly exceed the local firefighting capacity. It may also reflect the arrival of reinforcements, which may initially be relatively weak and may come with some delay due to the overall demand for resources in the country. This parameter cannot be influenced decisively by the fire prevention efforts on the island.

Further to the above, on a short time scale, the occurrence of a large fire is to a large extent a matter of coincidence. For example, many fires with very intense fire behavior, thanks to the prevailing wind, quickly reach the sea. On the other hand, an unexpected event, such as the mechanical failure of the first fire truck that was dispatched for initial attack to the fire of 4 August 2017, may lead to a disaster.

The difficulty of assessing the effectiveness of fire prevention in a short period of time is well-known and is probably one of the reasons governments and state agencies tend to neglect prevention and favor investments in fire suppression, which, in the short term, has more tangible results. Thus, in the case of Kythira, the satisfaction expressed by the firefighting authorities on the island, and the consideration of project findings in planning for the 2021 fire season, can be considered as positive signs.

The activities of fuel management and reforestation in the frame of the project have been to relatively limited extent of operational significance. However, the results stand as an example for the people on the island, have offered satisfaction, and have improved the community spirit of the participants. It is worth noting that in later meetings with the students they asked eagerly when such an activity will be repeated. It is quite likely that among them will be the future volunteers of the island.

On the negative side, there were a few people among the local authorities who remained negative about the whole effort. This could not be easily explained but may be the outcome of not understanding the broadness of the field of fire prevention, which does not simply include (often costly) technical measures, such as road maintenance, water sources, etc. It could also be a personality issue, as some people in power want to control everything.

Finally, it should be mentioned that although there are people on the island who were very concerned about its environment and its fire safety, especially after the 2017 fire, no initiative, such as that discussed here, was started spontaneously by them. They were happy to volunteer when the opportunity came, and devoted a significant amount of time, but there was always the need for scientific and technical guidance and cooperation from the two project partners. The gap caused by the measures for the COVID-19 epidemic resulted in minimization of activities, especially throughout 2020. Nevertheless, all those involved showed the necessary flexibility, including the funding agency which agreed to two deadline extensions.

5. Conclusions

It cannot be predicted with certainty what will happen on Kythira in the years after the end of the project, regarding continuation of the activities. There is an effort to establish a permanent network between the volunteers, supported as much as possible by the project partners (an environmental NGO and a state research institute), both with a long-term interest and commitment, as their will to contribute is not strictly limited by the existence

of a budget. They will try to obtain some further funding for the future to continue the work in Kythira and in similar places.

Concluding, it should be mentioned that projects of this kind are not easy to plan and carry out over large spatial scales. It is advisable that large prevention programmes (e.g., country level) should have certain guiding axes, common approaches, and supporting materials, but should also try to consider the local characteristics and to address the people locally. This can increase both effectiveness and efficiency. The lesson that has been learnt through the work described here is that a small yearly investment in fire prevention, assigning/employing highly motivated specialized individuals, with a small budget, to organize fire prevention activities such as those described above, can make a substantial long-term contribution to reducing fire loads and damage. This cost could be less per year than 3–4 h of flight time of aerial resources and the results could be tremendous. Furthermore, if a fire prevention network is developed (e.g., across Greece) to link, guide and support these individuals, monitoring and assessing the results, any weaknesses would be quickly resolved and the outcome would be impressive.

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Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable. The participating volunteers and other citizens remain anonymous.

Data Availability Statement: Publicly available datasets on forest fires in Greece were analyzed in this study. This data can be found here: https://www.fireservice.gr/el_GR/synola-dedomenon, accessed on 1 December 2021. The data presented in this study regarding house risk assessment and the questionnaire to the home-owners are available on request from the corresponding author. The data are not publicly available due to privacy reasons.

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Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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