Targeting To an Efficient Prevention Strategy of Forest Fires, Estimating The Fire Hazard on Islands The Case Study of Thasos Island, Greece

Stavros Sakellariou, Fani Samara, Stergios Tampekis, Athanasios Sfougaris, Olga Christopoulou

Abstract- Forests provide plenty of fundamental tangible and intangible goods to our planet, from vital chemical substances (O_2) to more economic issues (wood for economic activity and heating etc.). Hence, besides the ecological role of forest fires at our ecosystems, an efficient prevention strategy for confronting recurrent and destructive fires is considered of crucial importance. Primary objective of the paper is the estimation of fire hazard in Thasos island taken into consideration all the factors which are conducive to forest fires ignition and spreading. The pillar of the methodology lies in the fact that a unique fire risk map will be created based on the local characteristics, namely, topography (aspect and slope); fuels characteristics and the proximity from the road and urban network. Taking into account the individual contribution to the overall fire hazard of all these factors, we developed a model for estimating the fire hazard of any given area, overlapping all the essential thematic maps. We identified some critical areas which are characterized very susceptible and they situated in the interior and the western part of the study area, where mixed and very flammable fuels take place along with steep ground and south aspect. This project may be quite applicable to any territory, adjusted to the local differences and peculiarities. The importance of such a project is prominent, while it constitutes a project with great added value, least cost and if it may be combined with other supporting activities to maximize the forest fires prevention and safeguarding the cultural and ecological wealth.

Keywords: Forest fires, Fire hazard, islands, Thasos, Greece

I. INTRODUCTION

Forests provide plenty of fundamental tangible and intangible goods to our planet, from vital chemical substances (O_2) to more economic issues (wood for economic activity etc.). Hence, besides the ecological role of forest fires at our ecosystems, an efficient prevention strategy for confronting recurrent and destructive fires is considered of crucial importance. Consequently, the effective forest fires prevention aims to the conservation of the ecological richness of any national territory (endemic flora and fauna; retention of carbon dioxide and oxygen release; anticorrosive properties and protection of adjacent urban areas from flooding; Special places for leisure purposes etc.) and saves limited fiscal resources (for the restoration of damages etc.), while, at the same time, it enhances the socioeconomic cohesion and development of the local and regional population.

For this purpose, lately, it is attempted the detailed census of the local characteristics of any study area, exploiting the improvements and tools of the technological progress. Aim of this practice is the overall determination of the fire risk at the most vulnerable areas studying both the independent and collective contribution of the local factors to the fire ignition and evolution. The literature has focused on several methods for estimating the fire risk (Chen et al., 2003; Chen et al., 2004; Dong et al., 2006; Iliadis et al., 2002; Iliadis, 2005; Jaiswal et al., 2002; Kaloudis et al., 2005; Lapucci et al., 2005; Power, 2006; Sharma et al., 2012; Temiz and Tecim, 2009; Vadrevu et al., 2010), exploring at the same time not only the natural but also the anthropogenic causes of fire ignitions. It should be highlighted the fact that the estimated degree of contribution of both natural and anthropogenic factors to the fire ignition and propagation may be different relying on the local conditions (geomorphology, meteorological conditions, tourist burden etc.).

Hence, primary objective of the paper is the estimation of fire hazard in Thasos island taken into consideration all the factors which are conducive to forest fires ignition and spreading. After the fire risk determination analysis in the island, we provide some valuable suggestions for the adoption of preventative techniques and measures across the island and primarily at the most susceptible areas.

II. STUDY AREA

The island of Thasos is situated in the northeastern part of Greece and administratively belongs to the region of Eastern Macedonia and Thrace.

The length of the shoreline amounts to 115 km, while the area of the island is 380 km^2 (Wikipedia, 2015). Thasos constitutes an island of the Northern Aegean. The geomorphology of the study area is abnormal, as it seems from the huge mountainous areas. Despite the mountainous nature of the island, accessibility is considered quite satisfying due to the high density of forest roads. Figure 1 depicts the geographical position of the Thasos island in the context of the country as well as the administrative division of the island.

Finally, Thasos Island is characterized by rich vegetation, as it is reflected from the great variety of trees, such as olives, plane, fir, linden, cedar etc (Wikipedia, 2015).

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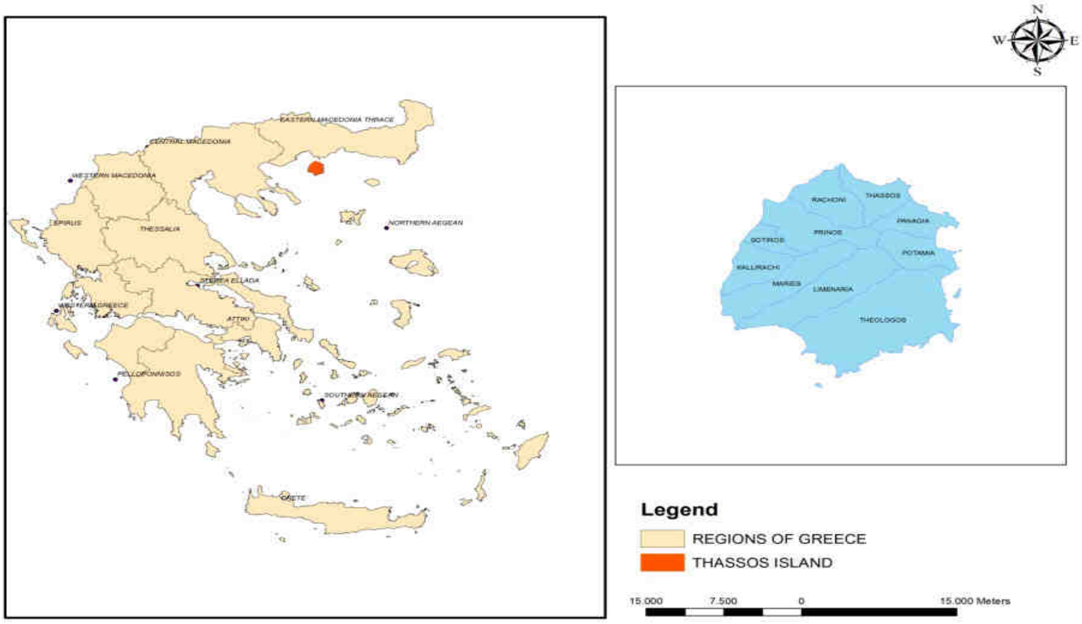

Figure 1. Geographical position and administrative division of the island of Thasos

Source: Tampekis et al., 2015

III. MATERIALS AND METHODS

The pillar of the methodology lies in the fact that the unique fire risk map will be created based on the local characteristics, namely, slope, aspect, fuel, distance from roads and distance from urban network (towns). The inputs used for our analysis include the following thematic maps: slope map; aspect map; fuels map; road network map and urban network map. All these maps resulted from pre-analysis procedures like digitizing and creating new thematic and analytic maps with the aid of Arc GIS 10.2.1.

At the second stage, the contribution of every factor (both natural and anthropogenic) to the fire hazard is estimated through the development of the appropriate thematic maps (through reclassifying process and establishment of the necessary buffers). These maps are created based on some certain criteria as presented in the table 1 and are in line with the similar projects in the international literature (Dong et al., 2006; Ertena et al., no date; Jaiswal et al., 2002; Power, 2006; Temiz et al., 2009). Thus, the potential fire risk of each factor was defined in five levels (from very low to very high fire risk). Final objective is the overlay of the previously mentioned dimensions weighted according to their effect to fire ignition and evolution.

Table 1. Local characteristics and estimation of their fire hazard

Slope (degrees)	Aspect	Fuel – Possible fire behavior	Width of buffers to roads (km)	Width of buffers to urban network (km)	Fire Hazard
0 – 5	Zero level	Very little or no fuels	0.5	-	Very Low
5 – 10	North - Northeast	Little fuels – Surface fire	0.4	4	Low
10 – 20	East - Northwest	Surface fire / torching	0.3	3	Moderate
20 – 30	West – Southwest - Southeast	Surface fire and crown fire	0.2	2	High
> 30	South	Full crown fire	0.1	1	Very high

Source: Own processing

Fire incidents tend to be more aggressive in steep slopes. So, when the slope level is increasing, the respective fire risk level is growing. In addition, steep slopes decrease the accessibility degree especially for the land fire brigade vehicles, a fact that will dramatically increase the financial and ecological cost. As regards aspect factor, generally, in Mediterranean basin, South aspect is considered to be more hazardous for starting a fire of very high intensity (GeoSTAC, 2014). Regarding the factor of fuels, which is considered the most influential to the overall fire risk, an alternative method has been used. Despite moisture content is a critical factor for fire evolution, we consider that this factor is quite variable and on the other hand, in the summer season, where the most destructive fires take place, this index could reach the lowest point. Therefore, having obtained the fuels inventory of the study area, we predicted the potential fire behavior based on the micro forest characteristics and dynamics. More specifically, the fire hazard is very low when there is very little or no fuels (urban areas etc.). On the contrary, in the case of dense and

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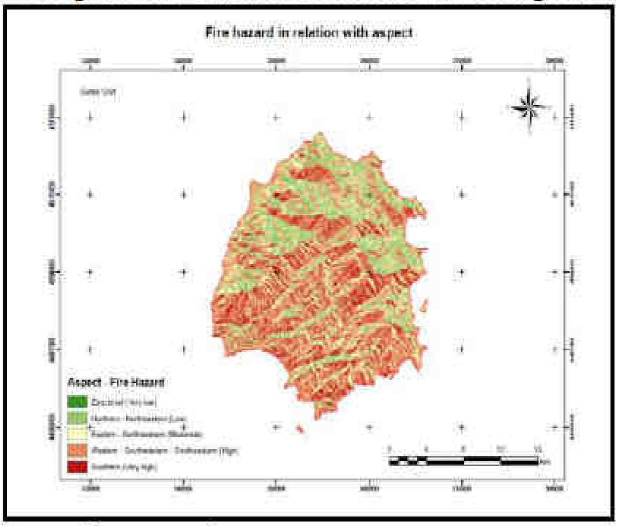
mix forested areas which "allow" the fire to be extremely aggressive (full crown fire), we defined these areas of very high risk. The most frequent anthropogenic causes for fire ignition are happening on certain spatial zones, where the socioeconomic activity takes place. These zones are the road and the urban network. Roads are considered "fertile" ground for fires, due to the fact that many incidents could originate either from accidental purposes or from intention (Ager et al. 2014; Syphard et al. 2008). To this end, we developed scalable buffer zones by 0.1 km determining as the most dangerous zone the first one of 100 m. where most activities take place (traffic, infrastructures, touristic activities etc.). We applied the same method for the urban network. Now the spatial zones are of 1 km width including the active perimeter (walking distance; in proximity with agricultural activities etc.) of each village and town.

IV. RESULTS AND DISCUSSION

After our analysis, we may observe the independent fire hazard of each natural and anthropogenic dimension. Maps 1 to 5 depict this phenomenon. Before the creation of the unique fire risk map, we should weight all the involved factors which are conducive to the overall fire risk, while the influence of each and every factor is variable. Maps 1 to 5 present the interrelation of fire hazard with the natural (topography: slope and aspect; fuels) and anthropogenic dimensions (proximity with the road and urban network). As described above, there are 5 classes of hazard, from very low to very high fire risk. As we may observe from these analytic maps, there are certain spatial patterns of fire hazard for each studied factor. The final objective of this analysis is the overlay of all these patterns, so we may develop an integrated fire hazard map, incorporating all the above information. Afterwards, we will be in position to locate the most susceptible areas and act with the most appropriate preventative measures.

Map 1. Fire hazard in relation with aspect



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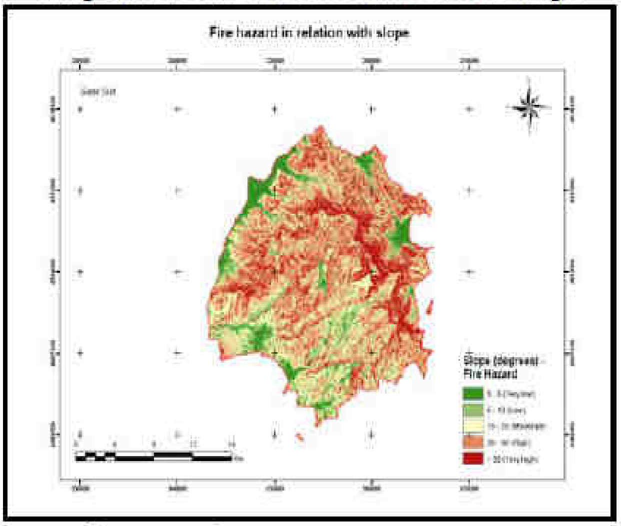
Map 2. Fire hazard in relation with slope



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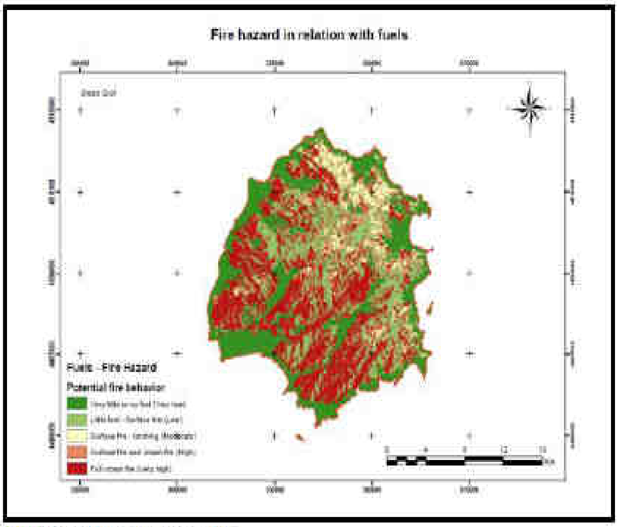
Map 3. Fire hazard in relation with fuels



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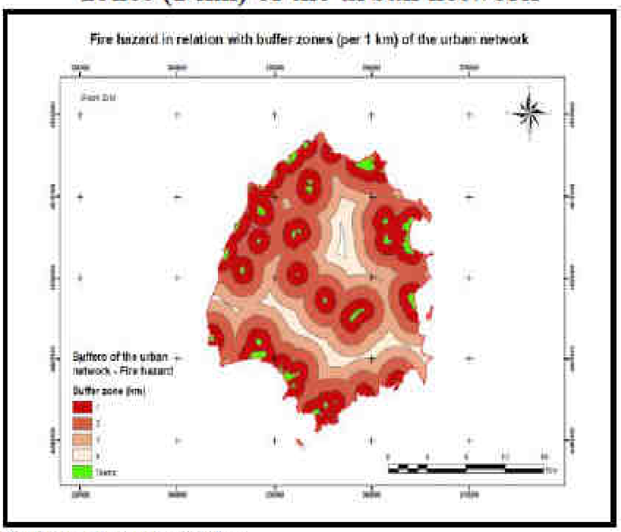
Map 4. Fire hazard in relation with buffer zones (1 km) of the urban network



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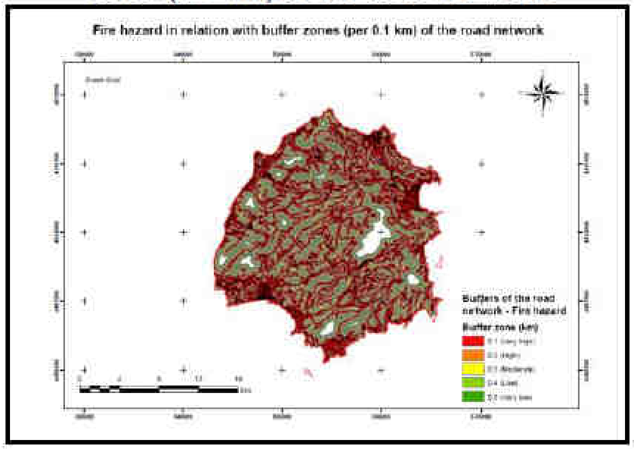
Map 5. Fire hazard in relation with buffer zones (0.1 km) of the road network



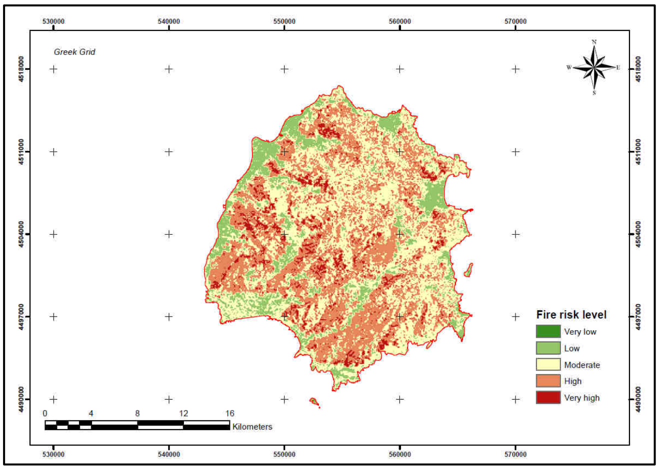
Source: Own processing

Following, we used the weighted overlay tool of the spatial analyst toolbox in ArcGIS in order to create the final fire hazard map. So, after we have converted all the previous thematic maps (maps 1 to 5) to a common measurement scale (5 classes from very low to very high fire risk), we provided a different weight to each factor according to their importance to the fire ignition and propagation (Arc GIS Resources, 2015).

It is obvious that without fuels, a fire cannot break out. This is why, we evaluated the fuels dimension as the most critical concerning this phenomenon and we ranked the fuels with a weight of 45%. Considering the significance of topography of the study area to the fire evolution as described above, we ranked both factors (aspect and slope) with a weight of 15% each. Moreover, we ranked the influence of road network with a weight of 15%, since many incidents begin from this network and especially in the summer season, where the tourist burden is growing more and more. In addition, it should be emphasized the importance of the roads to fire ignition, while the degree of road density in the island is quite high. Finally, we assessed the contribution of towns' proximity factor and ranked it with a weight of 10%, since many socioeconomic activities take place around these zones. This dimension received the lowest weight on the grounds that there is too much traffic inside and around these zones, so, a fire could be easily seen from the local people and the automobiles (Massada et al. 2009).

The following map (Map 6) depicts the final unique fire risk map after the integration (overlapping) of the five distinct analytic-thematic maps, as described above. As we can conclude from this map, we should emphasize the fact that areas of low fire risk is about 15% of the total area; areas of moderate fire risk is about 42% of the total area, while areas of high and very high fire risk is about 43% of the total area. Hence, we observe that about half area of the island faces many possibilities of igniting a fire due to the interplay of natural and anthropogenic factors. That is, the most vulnerable areas are located on the south and west part of the island. Hence, we should intensify our preventative measures primarily on these areas, as resulted from the above analysis.

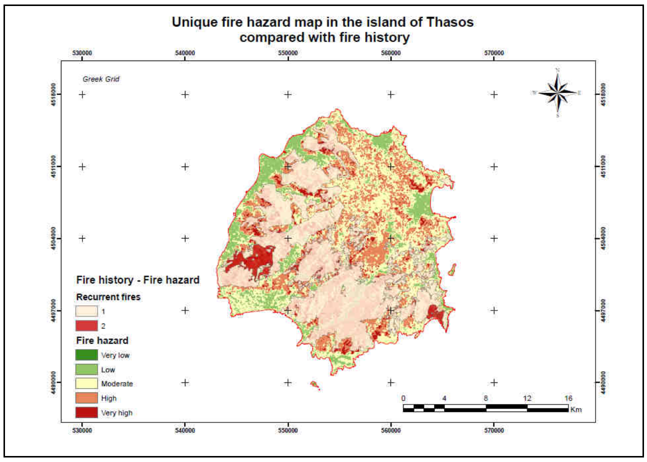
Map 6. Fire hazard map for Thasos island, Greece



Source: Own processing

For calibration purposes, we examined the relative validity of our model. Unfortunately, due to a great shortage of fire statistics in this geographic level (island), we cannot form solid conclusions, but it is a first approach and indication about the reliability of our methodology. The table 2 presents the fire statistics of the island with the estimated fire hazard of our map the burned area in absolute and relative terms. Map 7 depicts the overlay between the integrated fire hazard map and the past area burned.

Map 7. Unique fire hazard map compared with fire history



Source: Own processing

Table 2. Fire statistics of the island of Thasos along with the estimated fire hazard and the burned area

Fire Frequency	Fire hazard	Area burned (ha)	Percentage of the total burned area
1	1	0.5	0.0%
	2	1,068.6	7.3%
	3	5,935.7	40.3%
	4	6,220.9	42.3%
	5	1,489.9	10.1%
2	1	0.0	0.0%
	2	86.5	9.2%
	3	231.1	24.6%
	4	524.5	55.8%
	5	97.3	10.4%

Source: NOA, 2014; Own processing

According to table 2, we may conclude the high degree of validity of our model, since, the majority of the real area burned belongs to the area of high and very high hazard. More specifically, where the fire broke out only once, 7% of the area burned belongs to the estimated area of low hazard; 40% of the area burned corresponds to the estimated area of moderate hazard; and 53% of the area burned belongs to the estimated area of high hazard. The validity of our model is strengthening even more, when we examine the areas where they face 2 fire incidents. In detail, 9% of the area burned belongs to the estimated area of low hazard; 25% of the area burned corresponds to the estimated area of moderate hazard; and 66% of the area burned belongs to the estimated area of high hazard. The results constitute a first positive indication that the majority of the areas that were burned are primarily areas of high and secondly of moderate fire hazard. Nevertheless, as we previously mentioned, the fire statistics data is quite limited, so we may not create certain conlusions. Definitely, there is fertile ground for future research on this field.

V. CONCLUSIONS

Main objective of the paper was the creation of a unique fire hazard map based on the most influential characteristics of the island, such as the topography (aspect and slope); the fuels characteristics and the proximity from the road and urban network. Taking into account the individual contribution to the overall fire hazard of all these factors, we developed a model for estimating the fire hazard of any given area, overlapping all the essential thematic maps.

According to the results, we identified some critical areas which are characterized very susceptible and they situated in the interior and the western part of the study area, where mixed and very flammable fuels take place along with steep ground and south aspect. As it seems reasonable, the perimetric areas of the island are characterized of lower hazard, since they are located near the coast except in the western part, where dense shrubs with south aspects and deep slopes can be found.

This practice is quite applicable to any territory, adjusted to the local differences and peculiarities. The importance of such a project is prominent, while constitutes a project with great added value and the least cost. This project could be the first preventative measure which may be combined with other supporting activities such as the efficient distribution of observatories especially at the most vulnerable areas; the optimal allocation of the firefighting forces; projects regarding fuels treatment where necessary; and limitations of accessibility in critical and sensitive areas in the peak of summer season.

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