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Wildfire Prevention and Mitigation: The Case of Southern Greece

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WILDFIRE PREVENTION AND MITIGATION: THE CASE OF SOUTHERN GREECE

A Thesis Presented

by

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DEDICATION

This work is dedicated to the people who lost their lives during the August 2007 wildfires in Greece. May the country never again see the face of such a tragedy that will claim the lives of so many.

ACKNOWLEDGEMENTS

I have always been a firm believer of chance. And it is chance that gave birth to this project. The topic of the master's thesis at hand was conceived over a cup of coffee at the World Bank headquarters in Washington D.C. It was the idea of Dr. John Baffes, a senior economist at the Bank. His support throughout the process of the research and particularly the field work was critical. Without his encouragement, chances are that I would have packed up and headed back to the States after the first 10 days on the field. Instead I stayed for 10 weeks.

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ABSTRACT

WILDFIRE PREVENTION AND MITIGATION: THE CASE OF SOUTHERN GREECE

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The summer of 2007 was the worst wildfire season ever recorded in Greek contemporary history with approximately 270,000 hectares of land burned throughout the country. The area most severely hit was the Peloponnesian state of Elia. Econometric analysis with the use of primary and secondary data was carried out in an attempt to disentangle the effects of a variety of factors in the spread of the fire. The findings identified villages in low altitudes and steep slopes as the ones most vulnerable to the risk of wildfire. Wind speed played a significant role in exacerbating the blazes. As far as human factors are concerned population density was negatively associated with wildfire spread. In addition, the more olive groves were found within the boundaries of a village the less damage the settlement was found to have sustained. Finally, participation of local people in fire abatement efforts was significant in reducing wildfire risk.

. We conclude that public policy should consider a more holistic approach to wildfire management; one that would incorporate the “human-fire” interactions more thoroughly and balance the importance of ecological variables and social parameters in both wildfire prevention and mitigation.

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CHAPTER 1

WILDFIRES FROM A SOCIAL SCIENCE PERSPECTIVE

1.1 Introduction

When most people think of wildfires, the first things that come to mind are images of destruction and suffering[1]. Burning forests, destroyed houses, firefighting airplanes are all things commonly associated with forest fires. Nevertheless, wildfires are nothing but a natural phenomenon that existed way before human presence on this planet and are likely to continue long after that presence seizes to exist (Dafis, 2007). They play an integral part in the life of many ecosystems. Some of their benefits include the triggering of the regeneration processes of trees, the release of soil nutrients, the improvement of forest health to name only a few. Unfortunately, they also bring along a series of risks for sensitive ecosystems and often threaten people's lives and property (Arvai et al., 2008). Nevertheless, man should not fear wildfires. Rather, as with any natural phenomenon, he should comprehend their behavior and characteristics, respect them and hopefully learn to live with them (Konstandinidis, 2003).

1.2 Fire as a chemical reaction

Fire is the result of a chemical reaction between three elements: 1) oxygen, 2) fuel and 3) heat. These elements are known to constitute the fire triangle illustrated on figure 1.1. Even if one side of this triangle is missing, then fire ceases to exist.

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1 In March 2008, the author gave a presentation regarding wildfire prevention and mitigation at a private high school in the city of Athens, Greece. At the beginning of the presentation, members of the audience, consisting of 120 freshmen students, were asked to note on a piece of paper the first word that they though of when hearing the word "wildfires". 86% of the respondents wrote the word "destruction".

Fire is the chemical reaction between several elements. The procedure that leads to the spread of forest fires (given an initial ignition point) could be described as follows: High temperature heats up fuel, which is most commonly associated with ground vegetation in a forest. Different types of vegetation have various water content measured in degrees of humidity. The longer the vegetation is heated the more of that water evaporates. Once ground fuel is heated to least 100 ^{o}C most of it's water content has disappeared. At 300 ^{o}C combustible gases are created. When these gases come into contact with oxygen in the air a chemical reaction is put to place. The visible part of that reaction is a flame. It's visibility is attributed to the radiation that is emitted. The temperature of the flame exceeds 1,000^{o}C (National Agricultural Research Foundation, 2007). Note that the flame of a cigarette bud generates temperatures of approximately 600-800 ^{o}C (Konstandinidis, 2003).

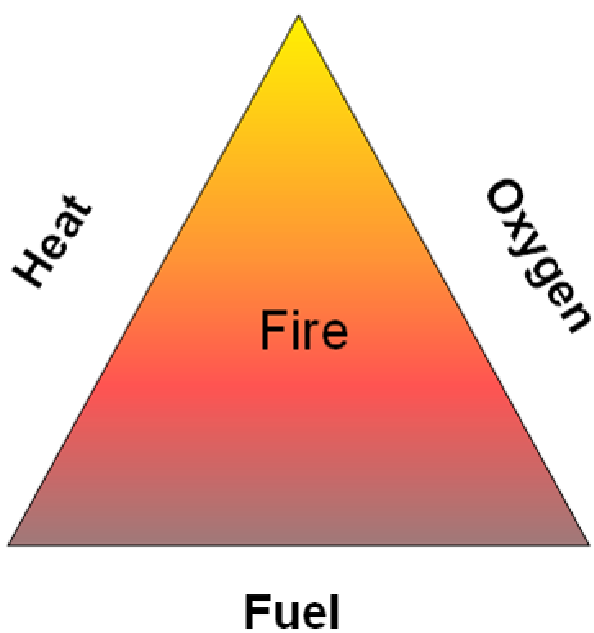

Figure 1.1: The fire triangle. Source: National Agricultural Research Foundation (2007)

1.3 Wildfires as a natural phenomenon

Wildfires have been studied extensively from a natural science perspective (Cortner, 2008). Among all natural phenomena, they are perhaps the one with the highest degree of predictability (Xanthopoulos, 2007a). A considerable amount of research has gone into understanding and predicting the behavior of wildfires. Several models have been developed (such as BEHAVE and FARSITE) that assist fire scientists in monitoring wildfires and forecasting their rate of spread (Andrews, 1985; Finney, 1998). These models take into account a series of ecological variables (mainly topography, wind speed and direction, fuel moisture, etc.) in an attempt to explain and predict the behavior of wildland blazes.

Wildfires scientists have developed consistent theories regarding the factors that affect the spread and intensity of a forest fires. We know for example that steep slopes exacerbate the speed at which a fire is burning, or that wildfires are less common in higher altitudes. In addition, the relation between meteorological conditions and wildfires is also well established. Wind speed and temperature are positively associated with a fire's rate of spread, while air humidity sets an obstacle to a fire's path (National Agricultural Research Foundation, 2007; Konstandinidis, 2003; Smith 2001).

1.4 The social science perspective of wildfires

However, fires have not been studied as extensively from a social science perspective. As human presence in nature dominated forest ecosystems has started to increase rapidly, so have the ways in which man affects the behavior of wildfires. Urban expansion has lead to the creation of the so called "Wildland Urban Interface zones" (WUI). The term refers to a geographic area in which flammable wildland fuels are in close proximity to urban and/or suburban structures (Boulder County Wildfire Mitigation Group, 2001).

A series of extreme fire seasons in the US (i.e. 2000, 2002 and 2003), and the rest of the world, appear to be influencing the focus of conventional wildfire management. During the last few years considerable amount of research is being conducted in what is known as fire social science (Cortner, 2008); a field in the intersection of economics, wildfire management as well as a wide range of social science topics (including but not limited to, individual attitudes and perceptions, institutions, etc.). This field attempts to investigate the risks that wildfires pose to communities by employing methodologies drawn from the vast pool of social sciences.

Perhaps one of the biggest potential contributions of the fire social science is the fact that it can assist decision makers by providing them with a more holistic framework of the factors that affect fire behavior; a framework that would incorporate the so called "human-fire" interaction (Prestemon et al., 2002). This is particularly important given that in recent years there has been an increasing trend in the occurrence of wildfires attributed to anthropogenic factors, either accidental or deliberate.

An example of the "human-fire" interaction is the way in which the human factor affects certain attributes of the landscape, the relationship between the socio-economic characteristics of a community and the occurrence/intensity of wildfires and the changes that agricultural management or housing development cause to the continuity of combustible ground fuel. All the above issues could play a significant role in enhancing the understanding of wildfire behavior. Knowledge of those factors could improve wildfire management (be it prevention and/or suppression) and ultimately reduce wildfire risk in wildland ecosystems with a strong human presence.

1.5 Literature review

The following section is an attempt to review the existing literature on fire social science. Several approaches of modeling wildfire ignition, spread and intensity that incorporate social aspects will be presented. The goal is to familiarize the reader with the existing work on the field and to set the scene for the analysis that will be conducted by the author.

A considerable amount of literature has focused on an attempt to identify the factors that influence fire incidence. Donoghue and Main (1985) investigated the relation between human caused wildfires (HCW), in 27 states of the eastern USA for the period between 1970 to 1981, and four factors, namely: latitude, weather, population density and law enforcement. They used a panel of 324 observations (i.e. 27 states for 12 years) drawn from the USDA Wildfire Statistics. Their estimation was based on a simple OLS model where a logarithmic transformation was applied to the law enforcement and the dependent variable. Results are presented on table 1.1.

Their findings suggest that Northern states suffer less HCW than their counterparts in the south. Thus, as latitude increases HCW decrease. The weather factor was comprised simply by incorporating precipitation data, hence the negative sign of the coefficient. Population density creates a higher danger for HCW occurrence, although the relationship is not linear as indicated by the negative sign of “population density squared”. In addition, as illustrated in Altobellis (1983), who conducted a survey among 13 Southern states with regards to fire occurrence, population density explains only a very small percentage of the variation in the fire occurrence rate. The law enforcement variable was significant only when used in a model where the dependent variable consisted of arson-caused wildfires. In the latter model, the data provide evidence to suggest that increased enforcement efforts decrease arson rates.

Table 1.1: Estimation results regarding human-caused wildfires. Source: Donoghue and Main (1985)

	Dependent variable
Independent variables	Human-caused wildfires
Intercept	5.76*
Latitude	-0.053*
Weather factor	-0.721*
Population density	0.160*
Population density squared	-0.013*
Law enforcement	-0.016
R^2	0.49
F-Value	61.28

Note that * denotes statistical significance at the 1% level.

Prestemon et al. (2002) take the literature a step further by estimating four different wildfire risk functions based on various ignition causes. They use three different functions for: arson, accidents and lighting. They also estimate an aggregate function that includes all of the above mentioned ignition sources.

The authors use a panel of 176 observations (39 counties in the state of Florida over a 5-years period, 1995-1999) and estimate an OLS log-log model. Their aim is to investigate the relation between burned forest area at a specific year and a series of explanatory variables, namely: annual burned forest area for the past 12 years, current and 2 year lags of prescribed burning permits for seed preparation, current and 2 year lags of traditional prescribed burning permits, 3 year lags of the county's pulpwood harvests, the housing count in the county, a vector of underlying ecological variables (i.e. land form, soils, potential vegetation communities, etc.) and the Nino 3 sea surface temperature (SST) anomaly in degrees centigrade. The data used came from a wide variety of sources, namely: the Florida Division of Forestry (area burned and prescribed burning permits), the USDA Forest Service (pulpwood harvest volumes), the Bureau of Economic and Business Research (housing count) and finally the National Oceanic and Atmospheric Administration (weather data).

The estimation of the model yields some very interesting results. The authors suggest that past wildfires within the last 7 years have a suppressing effect on current area burned. According to their reasoning, past wildfires act preventively in the sense that they consume combustible fuel from the ground, thus inhibiting future ignitions. The housing count variable proved insignificant. The authors justify this by the fact that there is a two way relation between number of dwellings and wildfire risk. Intuitively one would expect that more houses would mean greater wildfire risk, since there would more people that could start a fire either accidentally or deliberately. However, risk is lowered by the fact that suppression efforts are more effective (i.e. more manpower available) and accessibility is generally better in densely inhabited areas. Finally, prescribed burning permits variables, presented either counter-intuitive or non-significant signs. In addressing this issue the authors argue that perhaps prescribe burning permits did not always result to the application of prescribed burning per se.

Mercer and Prestemon (2005) take the examination wildfire production functions (WPFs) a step further. They empirically estimate 3 types of WPFs, namely: 1) fire events (i.e. ignitions), 2) fire aggregate extent (i.e. total area burned) and 3) a combination function of fire effect and aggregate extent (i.e. fire intensity). The main innovation, compared to the Prestemon et al. (2002) paper, is the addition of the following socio-economic variables: unemployment rate, poverty rate, number of police officers, population and housing density. The authors use a panel of 297 observations from several counties in the state of Florida. Some of the variables (i.e. area burned, prescribed burning, etc.) are similar to the Prestemon et al. (2002) paper. The newly introduced variables were obtained from the US Department of Commerce, the Bureau of Census (poverty data), the Florida Department of Law Enforcement (police data), the US Department of Labor and the Bureau of Labor Statistics (unemployment data).

Table 1.2 below summarizes the signs indicating the direction of the relation of each of the above right-hand side variables with each of the three dependent variables.

Table 1.2: Direction of impact of wildland–urban interface variables on wildfire ignitions, acreage, and intensity. Source: Mercer and Prestemon (2005)

	Wildfire ignitions	Wildfire area	Wildfire intensity-area
Population	+	+	+ (insignificant)
Poverty	–	+	+
Unemployment	–	–	–
Housing density	–	–	–
Police	–	– (insignificant)	+

The authors admit that their results may seem contradictory. They do argue however that the relations in place here are by no means causal, but rather correlative. In defense of their analysis their support that prescribed burning tends to be implemented in low income areas, with a lower educated population. That is why higher unemployment is associated with lower rates of area burned and fire intensity. On the other hand, in analyzing the ambiguity in the signs of the poverty variable, they argue that the positive relation with area burned and intensity is explained by the fact that poorer counties have fewer fire fighting resources and thus lower capacity for initial attack of a blaze. As far as the police variable is concerned, Mercer and Prestemon, suggest that highly populated areas have large enough law enforcement departments that help reduce the number of ignitions. However, the same areas apply prescribed burning on a lower scale, thus increasing the intensity of wildfires.

The justification in the difference as far as prescribed burning rates comes both from the nature of the forest itself (i.e. whether or not prescribed burning can be applied given tree species), but also from resistance of the local population. In less densely populated Wildland Urban Interface (WUI) areas, forests are managed intensively and people are less likely to object to prescribed burning practices. This is not the case in WUI areas with higher population density and more expensive dwellings. Inhabitants tend to value the pristine environment highly in those areas and often object to the implementation of prescribed burning.

In conclusion, the authors argue that given the significance of the socio-economic variables in their model policy makers should take these factors into consideration when determining wildfire management strategies and should not rely exclusively on ecological variables. Failure to incorporate the "human-fire" interaction into wildfire strategies may lead to considerable bias and inhibit the optimal allocation of resources.

Overall the work presented in this section has focused on establishing the relationship between social factors and wildfire science. Scientists have attempted to examine the relationship of a series of socio-economic variable (i.e. poverty, unemployment, population and housing density) with a number of wildfire attributes, namely ignition, spread and intensity. Results so far suggest that the incorporation of “human-fire interactions” in wildfire management, could significantly reduce wildfire risk.

1.6 Wildfire evacuations

A more specialized segment of fire social science is one that focuses on the issue of evacuations; a critical part of the wildfire suppression procedures. There is a considerable debate in place on whether citizens have the right to protect their property during a wildfire, versus fleeing a settlement in favor of making sure that no lives are threatened.

Decisions with respect to evacuations policies play an integral part in wildfire management. In the aftermath of Ash Wednesday, one of the most devastating wildfires in the history of Australia that killed 75 people and caused widespread damages in February of 1983 (Department of Sustainability and Environment of the State Government of Victoria, 2007), a parliamentary inquiry arrived at important conclusions. Investigators challenged the evacuation orders that were issued during the wildfires, arguing that even in great emergencies, the need to resort to evacuations is not justified (Murray, 1999). Australia has since faced out mandatory evacuation policies in favor of giving the citizens the right to take shelter in their houses (Kim, 2004).

Apart from determining the necessity to evacuate, considerable work has been undertaken in the area of exploring people’s behavior with regards to evacuation. Several studies have attempted to identify the factors that influence people in their decision to comply with evacuation orders or not. In one of those studies, Fisher et al. (1995), examined the evacuation behavior of residents in the vicinity of a burning paint factory in Ephrata Pennsylvania in May 1990. The authors interviewed a total of 83 households and employed simple statistical methodology (i.e. comparison of means) in order to analyze the gathered data. According to their findings, households were more likely to follow evacuation orders issued by the authorities if: 1) the warning message was communicated effectively and clearly, 2) the frequency of the warning message was high enough (i.e. most people were contacted at least once) 3) previous warning messages were accurate and, 4) the household included children. An interesting issue raised by the authors is that in emergency situations people's behavior is affected primarily by advice from the media, then by law enforcement agents and fire fighters and lastly by friends and relatives.

Mozumber et al. (2008) conducted a mail survey of 1,018 households in the East Mountain area outside Albuquerque, New Mexico. The authors were interested in determining people's behavior in the event of a wildfire. Survey participants were asked whether or not they would evacuate the settlement under a mandatory vs a voluntary evacuation order. A bivariate probit model was subsequently estimated. According to the findings female household members have a higher probability of intended evacuation as opposed to men. In addition, people were also more likely to evacuate if they felt they could securely find accommodation (i.e. in a motel/hotel or the house of a relative/friend) after fleeing form their dwellings. On the other hand, political affiliation with the Republican Party as well as ownership of livestock or pets was found to decrease the probability of intended evacuation. Finally, people that placed a high value on environmental amenities were also less likely to evacuate.

1.7 Conclusion

Wildfires are a natural phenomenon that plays an integral part in the life cycle of many forest ecosystems. Just like any other part of nature it is not to be feared. Rather, man needs to learn to live with wildfires; understand them and respect them.

Learning to live with wildfires requires in depth consideration of the various ways in which human related factors influence the occurrence and behavior of wildfires. So far "human-fire" interactions have not received the necessary attention in conventional fire science. However, social fire science attempts to incorporate a series of socio-economic variables in traditional fire models as well as taking into account ways in which man alters the landscape and thus the behavior of wildfires.

Our project is an attempt to contribute to the emerging field of social fire science. By examining the case of a series of catastrophic blazes in Southern Greece during the summer of 2007 we will explore the relationship between several human related variables and wildfires.

CHAPTER 2

WILDFIRES IN GREECE

2.1 Introduction

The current chapter provides an insight into the issue of wildfires in Greece. At first an overview of the wildfire history of the country is provided, followed by an analysis of the August 2007 season. The latter was regarded as the worst wildfire season ever to be recorded in Greek history.

2.2 Country profile

Greece (illustrated in figure 2.1) occupies the south part of the Balkan peninsula located on the southeastern tip of Europe. It has the second, after Norway, longest coast line in the continent (15,000 km) and 3,000 islands of which 63 are inhabited.

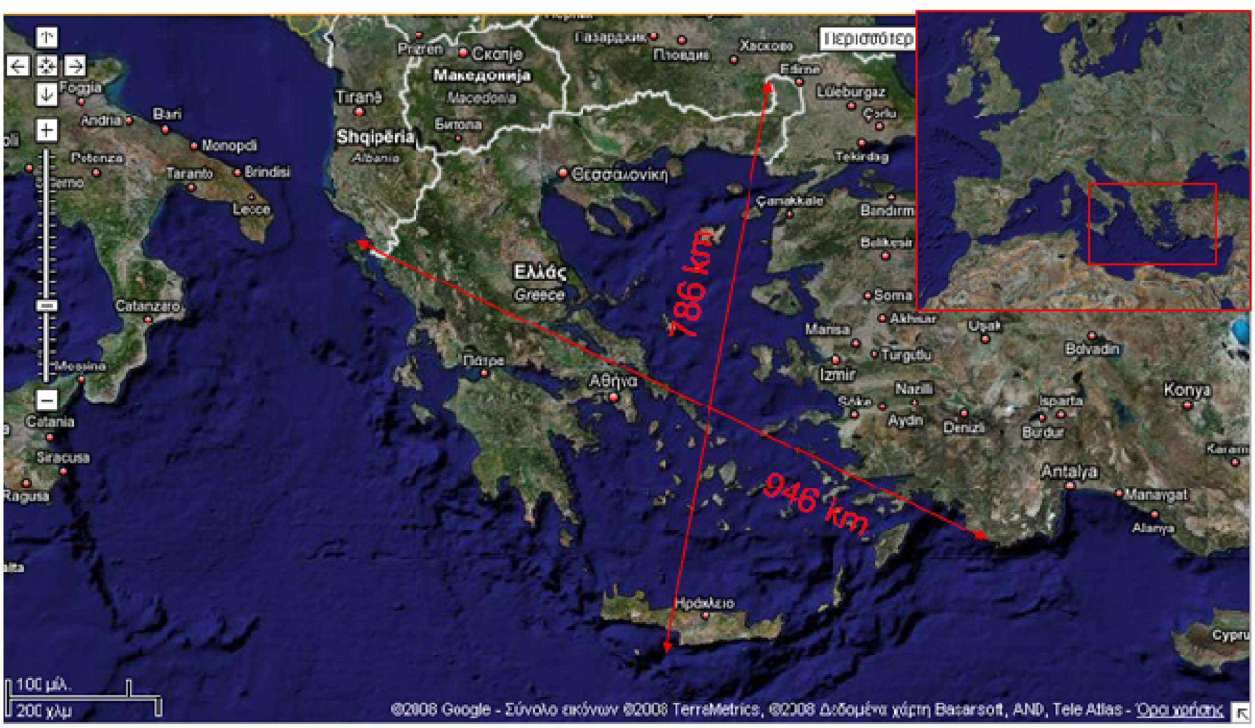

Figure 2.1: Geographical location of Greece. Source: GoogleMaps.com

The landscape is dominated by mountains, with fertile soil restricted to coastal lowlands. Greece has a typical Mediterranean climate with mild, wet winters and hot, dry summers (CIA, 2008; Tsiourtis, 2002). Mean yearly temperature presents significant variations ranging from 14.5^o C in the northern part of the country to 19.5 ^{o} C in the very southern island of Crete (Xanthopoulos, 2000).

Greece covers an area of 131,957 km^2 (approximately 5 times the state of Massachusetts) out of which 37,520 km^2 are covered by forests (approximately 28% of total area) (World Bank, 2008).

2.3 Wildfires in Greece

Wildfires have lately become an ever increasing problem in Greece. The causes of this problem could be attributed to a series of ecological but also socio-economic factors. To gain a better understanding of the latter one would need to look back into the contemporary history of the Greek countryside.

Within the past 50 years Greece has undergone serious social and demographic changes. With the end of the Greek civil war (1945-1949) a rapidly growing urbanization movement was initiated. People started moving into the big cities seeking employment opportunities and a better way of life. Reaching its peak around the end of the 1960s, urbanization led to the isolation of many rural areas and the over-population of urban centers. That movement influenced the way of life around the country (Clogg, 2002).

Traditional income generating activities such as animal husbandry and agricultural production began representing an even decreasing percentage of national GDP. A steady decline in rural population was observed. As a result rural land was left unmanaged. There was less demand for fire wood and grazing land, agricultural fields were left uncleared, paths in the mountains were no longer needed and the availability of labor in the periphery was constantly diminishing. Rural dwellers, traditionally the "managers" of forest land, were no longer attached to the woodlands as a means of making a living. Over the years Mediterranean markets for forest products were steadily shrinking, thus removing the incentive for investment opportunities in forest management (Bassi et al., 2008). A representative example is that of Greek resin collectors. Once a main occupation for the rural population, today only a few resin collectors have remained. They provided a series of important forest management services by maintaining paths within woodlands in order to facilitate the transportation of goods, practicing tree thinning by cutting down older trees in an effort to create more space for the growth of new stands and engaging in fire prevention by removing ground combustible fuel since the forest was their main income generating resource and they had a great incentive to protecting it (Xanthopoulos, 2000) The main consequences of all of the above are an ever increasing accumulation of biomass in the Greek forests, as well as a decrease of the population that has traditionally been managing those forests. Thus, the incentive to protect woodlands from natural threats, such as wildfires, is gradually decreasing (Morehouse, 2007).

The late 1970s and early 1980s saw yet another cultural change in Greek lifestyle. Economic prosperity, coupled with increased pollution in urban centers, made city dwellers start seeking alternative destinations. Many people started leaving the cities during the summer months and building vacation houses in coastal areas and mountain villages. Thus, the Wildland Urban Interface (WUI) made its appearance in Greece (Xanthopoulos, 2007a).

Tourism, one of the country's strongest and most lucrative industries, plays it's own role in the shaping of the rural life. The summer months (late May to early September) are the peak tourist season for Greece. Travelers from all over the world reach mainly the islands, but also the Greek mainland in search of pristine beaches. This vast accumulation of visitors in rural areas during the hot and dry summer months creates additional wildfire risks. That is because tourists often engage in recreational or everyday activities (i.e. barbeques, camp fires, smoking, etc.) that can become reasons for accidental fires (Xanthopoulos, 2000; Konstandinidis, 2003).

Furthermore, demand for land on which summer houses and touristic lodging are built upon, greatly exceeds availability. The Greek legal system greatly impedes any change in the use of forest land, let alone does it allow for construction to take place in forests (Spiegel Online, 2007). Thus without the possibility of building on or allowing for development on forests, shortage of land led to skyrocketing land prices, an effect that motivated arsonists. Wildfires started to appear with an increasing frequency in areas where development land was in great demand. Soon after the fires, houses and tourist lodgings would spur up in land than was previously forested. Lack of law enforcement as well as cases of corrupt officials in the public sector allowed for housing development on burned forests to take place. In addition, the absence of a comprehensive land registration system in Greece facilitates the work of developers, given that the exact borders between forest and agricultural land can often be disputed (The Economist, 2007).

An additional stress on forest ecosystems is created by animal husbandry. Overgrazed land has been creating increasing problems for sheppards that have been facing difficulties in sustaining a stable source of feed for their animals. They often result in setting fires on low vegetation areas, in order to stimulate new growth that would provide additional feed. However, this practice posses severe dangers to forest ecosystems, since it leads to soil erosion and desertification (Xanthopoulos, 2000)

All of the above mentioned factors have led to the increase of wildfire incidents in Greece over the past years. From 1980 until 2000 55,000 hectares of land were burned, on average, in Greece every year. The same figure for the years 1955-1973 reaches a mere 11,500 hectares. The difference is tremendous and could be attributed to all of the factors mentioned previously (Xanthopoulos, 2000). Figure 2.2 below, provides a graphical illustration of burned land between the period of 1980-2000.

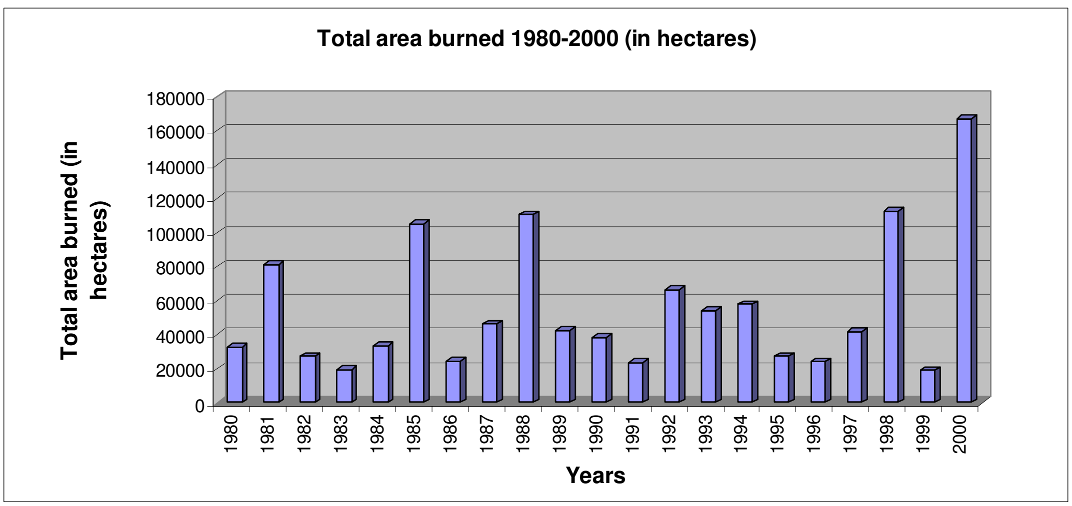

Figure 2.2: Total area burned by forest fires in Greece during the period 1980-2000. Source: Xanthopoulos (2000).

2.4 Wildfire management structure

The Greek Forest Service was responsible for all three aspects of wildfire management (i.e. prevention, abatement and ecosystem restoration) until the year 1997. In 1998 however, wildfire suppression responsibilities were transferred to the Fire Brigade. Ever since that change took place the Forest Service has seen its staff, equipment and budget decrease significantly (The Economist, 2007). As a result fire prevention efforts were curtailed. Over the years the Forest Service has concentrated in managing woodlands in high elevations. The later are considered the most lucrative of all in terms of the quality and quantity of the timber they produce. However, lower elevation forests are being left completely unmanaged, particularly after the decrease in the number of resin collectors (Xanthopoulos, 2000). Thus the accumulation of biomass is immense, a fact that makes fire suppression considerably more difficult (Bassi et al., 2008). All around the world fire-prevention measures are an integral part of a comprehensive wildfire management system. The creation of fire-break zones, the implementation of prescribed burning for the removal of combustible ground fuel as well as the maintenance of fire watches are only a few of these fire prevention measures (The Economist, 2007).

Ever since 1998, when fire suppression became the responsibility of the Fire Brigade, a large portion of the wildfire management budget was spent for the acquisition of abatement equipment and particularly of waterbombers (Xanthopoulos, 2007b). However, provision of equipment and training to ground personnel does not appear to be a top priority. A representative example is that of fire-to-fire control methods, such as backfire and burning-out. The latter are used successfully on a worldwide scale. However, the Hellenic Fire brigade does not endorse the use of those methods. In fact, fire fighters that apply those techniques have often been subject to disciplinary action (USAID, 2007)[2].

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[2] The author would like extend his gratitude to Mr. Prodromos Triantafillou, at the Public Affairs section of the US Embassy in Athens for providing a copy of the USAID (2007) report.

2.5 Wildfires in August 2007

The summer of 2007 was by far the most devastating wildfire season ever recorded in Greek history. Approximately 270,000 hectares of land were burned, an area equivalent to 86% of the US state of Rhode Island (Statheropoulos et al., 2007). Figure 2.3 illustrates the geographic location of the burned areas.

Figure 2.3: Burned areas of Greece during the summer of 2007. The red rectangle highlights the prefecture of Peloponissos. Source: Roy et al. (2007)

The red rectangle on figure 2.4 highlights the prefecture of Peloponissos. As one can observe, the greater extent of burned areas of the country are concentrated in that prefecture. Peloponissos is comprised of 7 states (i.e. Achaia, Argolida, Arkadia, Elia, Korinthos, Lakonia and Messinia). Figure 2.4 illustrates the location of those 7 states as well as the percent of area burned in each one, during the summer of 2007.

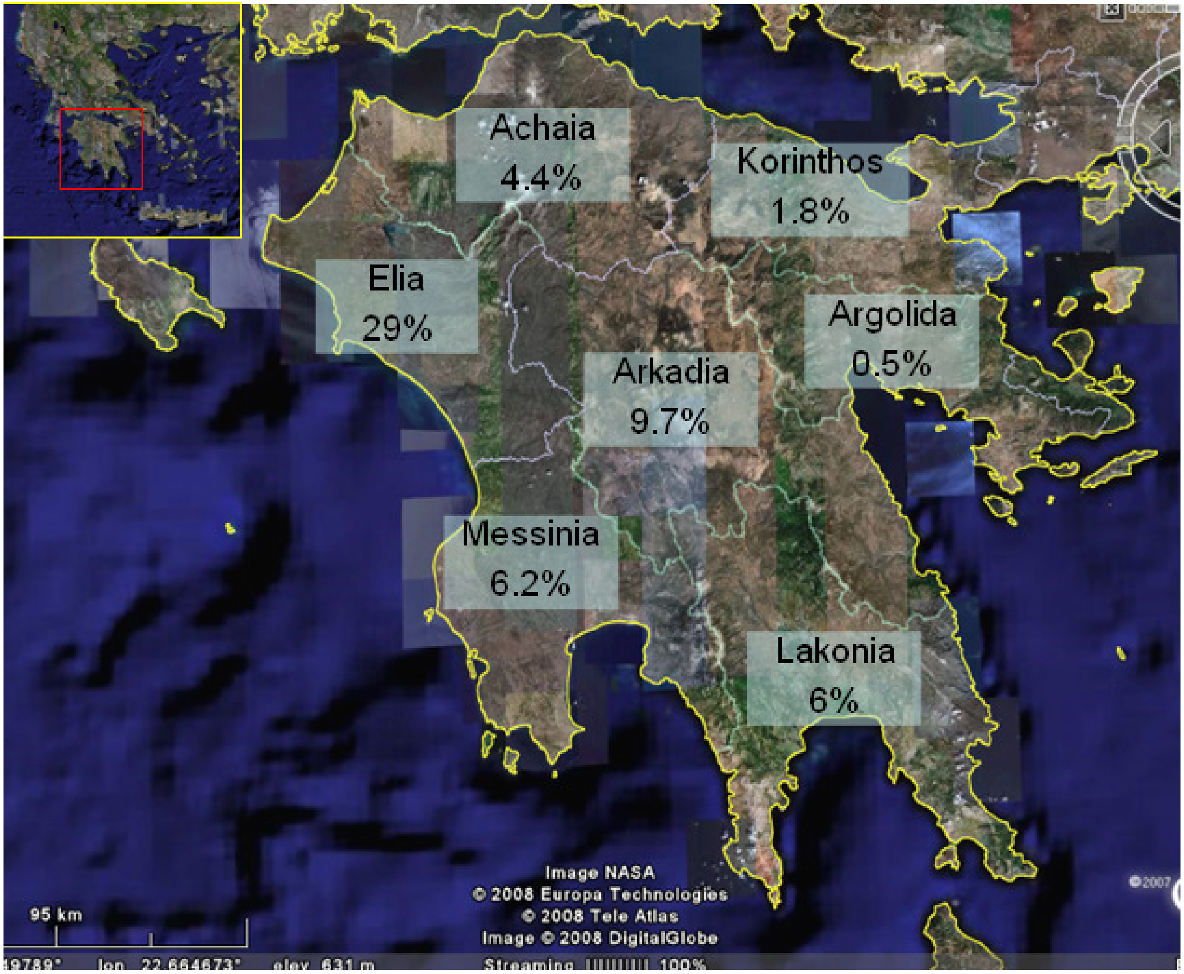

Figure 2.4: The 7 states of the prefecture of Peloponissos and their respective burned areas (in percentage). Data source: Statheropoulos et al. (2007).

The burned acreage of the prefecture of Peloponissos amounts to 180,310 hectares. That was the result of a series of blazes staring from early July and lasting until early September. However, the most extensive damage took place towards the end of August. From August 24th till the 28th wildfires burned through the Peloponnesian state of Elia, where 77,756 hectares of land (i.e. 29% of the state's area) were burned.

2.5.1 Wildfires in the state of Elia

Administratively the state of Elia is divided into 22 counties (the Greek equivalent term would be municipalities). Figure 2.5 provides an illustration of those counties along with their respective burned areas[3]. Each county is further divided into a number of towns and villages. In total there are 210 settlements in the state of Elia (including towns and villages). 168 of them were affected by the fires out of which 133 were severely burned (Agricultural University of Athens, 2007).

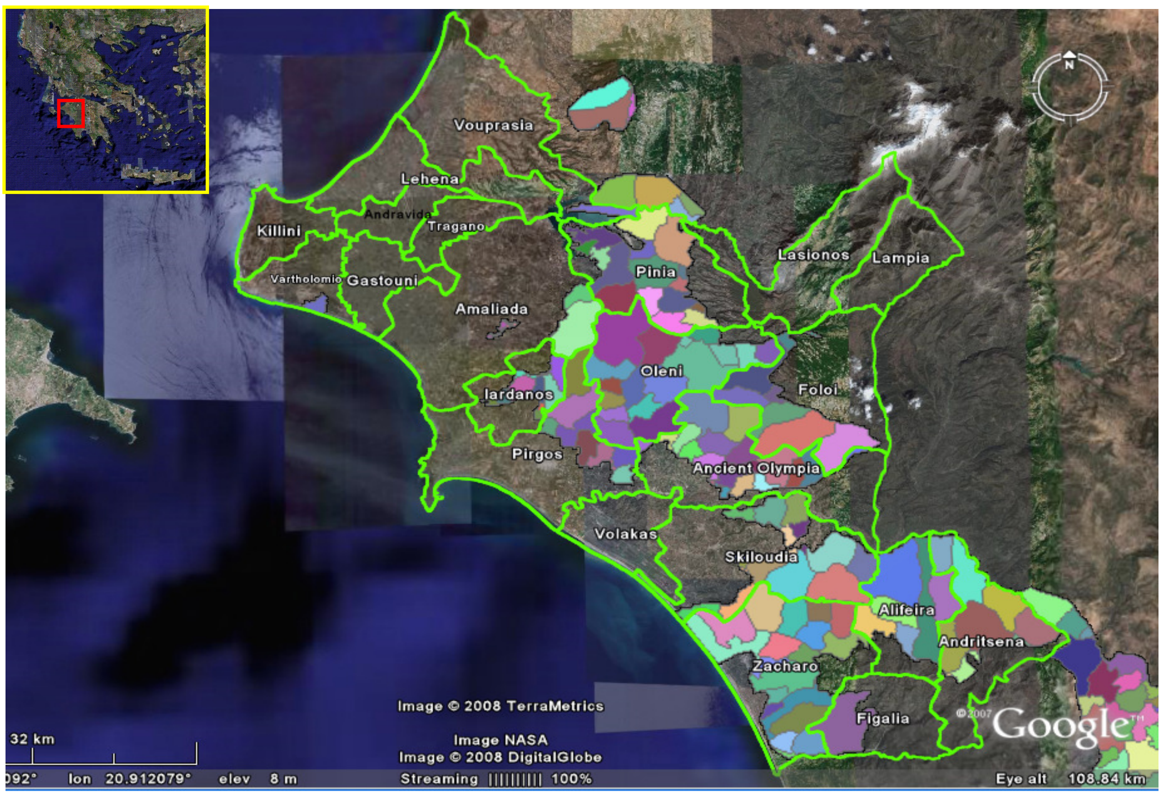

Figure 2.5: The 22 counties of the state of Elia, along with a graphical illustration of their burned areas (identified by the different colours).

3 The author would like to thank Mr. Aris Michos, a forester at the Forest Service of Pirgos, for providing a digital copy of the layer of the burned areas of the state of Elia. In addition Mrs. Christina Tsimi, a GIS specialist, for conducting the GIS software analysis of the data. Unless otherwise indicated, all figures including Google Earth images in Chapters 3 and 4 were developed using the data provided by Mrs. Tsimi.

Table 2.1 presents the burned areas for each of the counties of the state of Elia. The three most heavily affected counties were those of Alifeira, Oleni and Zacharo (based on the magnitude of area burned over total area).

Table 2.1: Burned areas for the counties of the state of Elia.

Municipalities	Burned area (in m^2)	Total area (in m^2)	Percent of area burned
Bolakas	13,192	70,790,000	0.0002
Lasionos	53,771	119,528,000	0.0004
Vouprasia	3,812,354	170,859,000	0.0223
Amaliada	21,435,544	251,945,000	0.0851
Foloi	33,909,570	174,202,000	0.1947
Pirgos	35,765,526	170,886,000	0.2093
Figaleia	21,471,543	89,175,000	0.2408
Ancient Olympia	51,628,015	178,944,000	0.2885
Iardanos	19,218,421	62,723,000	0.3064
Skilloudia	67,886,431	194,409,000	0.3492
Pineia	73,650,177	148,572,000	0.4957
Andritsaina	68,499,421	131,247,000	0.5219
Zacharo	117,522,228	187,047,000	0.6283
Oleni	109,269,537	152,231,000	0.7178
Alifeira	74,486,875	96,678,000	0.7705

The blazes brought with them devastating consequences. 68 people were burned during the summer of 2007 in Greece (Xanthopoulos, 2007b). Out of those, 46 lost their lives during the 5 day crisis period (August 24^{th}-28^{th}) in the state of Elia. Most of the victims died in their effort to evacuate burning villages, or during their attempt to save their property, such as animal stables, houses, or agricultural fields (Xanthopoulos, 2007b; Nodaros, 2008).

Scientists argued that weather conditions definitely played a key role in the spread of the fires. Three heat waves had hit Greece by late August, something that was never recorded before. In addition, lack of precipitation in southern Greece, where the region of Peloponissos is located, further exacerbated the intensity of the blazes. Nevertheless, it would be unjustified to solely blame weather conditions for the extent of the damage (Xanthopoulos, 2007b). The increased accumulation of biomass, the poor management of forests and the idea that wildfire management is comprised exclusively by fire suppression are all key aspects in the appearance of what scientists have come to describe by the term “Megafires” (Georgiopoulou, 2007). These are extensive wildfires that burn at 1000^{o}C creating their own climatic conditions that can even lead to the appearance of tornados (Lean, 2007).

The toll on houses and other infrastructure was also heavy. Approximately 847 residences were burned to the ground in Greece. The vast majority (815 houses) were located in the region of Peloponissos. Amongst them 524 were found in the state of Elia. Table 2.2 provides aggregate information regarding different types of infrastructure that were burned during the summer of 2007 in Greece. As one can observe the state of Elia, suffered the greatest number of losses compared to all other states that were affected by the blazes.

2.6 Conclusion

Social and cultural factors play a significant role in the wildfire problem of Greece. Housing development creates a great incentive for the removal of forested areas; an incentive that is often so strong as to lead to cases of corruption within the public service. What is more, the mis-management of the country’s forests is an issue whose accumulated consequences over the years took a hard toll during the 2007 fire season. In addition the fragmentation of the wildfire management strategy between the Forest Service and the Fire Brigade further exacerbates the danger that Greek ecosystems and citizens face from wildfires. The effects of all of the above factors were felt most severely in the region of Peloponissos and even more so in the state of Elia. The latter will be the state of interest of this study.

Table 2.2: Burned infrastructure during the summer of 2007 in Greece. Source: Ministry of Environment, Zoning and Public Works (2007)

<table>
<tr><th colspan="2"></th><th colspan="2">Residences</th><th colspan="2">Public buildings / Churches / Professional venues</th><th colspan="2">Stables / Warehouses / etc.</th></tr>
<tr><td>Region</td><td>States</td><td>Total destruction</td><td>Partial destruction</td><td>Total destruction</td><td>Partial destruction</td><td>Total destruction</td><td>Partial destruction</td></tr>
<tr><td rowspan="5">Region of Peloponissos</td><td>Arkadia</td><td>185</td><td>110</td><td>6</td><td>3</td><td>157</td><td>171</td></tr>
<tr><td>Korinthos</td><td>3</td><td>0</td><td>1</td><td>0</td><td>10</td><td>5</td></tr>
<tr><td>Elia</td><td>524</td><td>238</td><td>30</td><td>12</td><td>498</td><td>233</td></tr>
<tr><td>Lakonia</td><td>8</td><td>33</td><td>0</td><td>0</td><td>90</td><td>32</td></tr>
<tr><td>Messinia</td><td>95</td><td>40</td><td>4</td><td>2</td><td>33</td><td>8</td></tr>
<tr><td colspan="2">Total for region of Peloponissos</td><td>815</td><td>421</td><td>41</td><td>17</td><td>788</td><td>449</td></tr>
<tr><td rowspan="3">Other regions</td><td>Evia</td><td>31</td><td>245</td><td>0</td><td>2</td><td>29</td><td>95</td></tr>
<tr><td>Etolo-akarnania</td><td>1</td><td>2</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Attika</td><td>0</td><td>4</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">National Total</td><td>847</td><td>672</td><td>41</td><td>19</td><td>817</td><td>544</td></tr>
</table>

CHAPTER 3

FIELDWORK METHODOLOGY

3.1 Introduction

This chapter includes an analysis of the fieldwork. The most important methodological issues regarding the data gathering procedure are presented along with an analysis of important field research tools. We start by addressing the motivation and research question of the project.

3.2 Motivation

As analyzed in the previous chapter during the summer of 2007 Greece suffered its worst wildfire season ever recorded in the country's contemporary history. Approximately 270,000 hectares were burned (an area equivalent to the land coverage of Rhode Island). 68 people were killed in the devastating blazes and hundreds of houses as well as other types of infrastructure (i.e. schools, churches, community buildings, professional venues, etc.) were surrendered to the blazes (Xanthopoulos, 2007b). The main motivation behind the current project was to gain an in depth understanding of the causes that led to this unprecedented destruction; a destruction that many characterized as a national tragedy. In addition, another important goal was the willingness of the author to contribute towards the improvement of wildfire management in Greece as well as adding to the emerging literature of social fire science[4].

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4 The author would like to acknowledge the help of Dr. John Baffes (a senior economist at the World Bank). Dr. Baffes had the original idea that lead to the formation of this project and offered critical support during the progress of the fieldwork.

Soon after embarking on the project it was realized that the issue at hand was an extremely multidimensional problem; one that could only be approached efficiently if the research question was formed in such a way as to allow the researcher to work with secondary as well as primary data that could be collected within a narrow framework of time and a limited financial budget.

3.3 Research question

As illustrated in Chapter 1 the literature in social fire science has focused on modeling several aspects of wildfires including ignition, spread and intensity. At the very preliminary stage of formulating the research question, it was decided that the latter would focus exclusively on spread[5]. The aim would be to explain the differences in damages sustained by the several villages, given that a wildfire had, at minimum, reached some part of the settlement. In other words why did 80% of a specific village burn, while only 15% of an adjacent settlement sustained damages from the fire? The proposed model would estimate the percent of the area of a village that was burned as a function of a series of explanatory variables (i.e. demographic, meteorological, topographic as well as primary data gathered on the field). Special attention would be given to a series of human factors and their relationship to wildfire spread and intensity.

3.4 Analysis of the fieldwork

For the purposes of gathering the necessary primary data a 3-month long field research journey was organized. The fieldwork (that lasted from December 23nd 2007

[5] The main reason for which ignition was not part of the research question regarded limitations in data availability with respect to the exact causes of each blaze. The lack of such data, which became available only in April 2008 (Marnelos, 2008), would seriously inhibit any efforts to model wildfire ignition.

until March 22nd 2008) can be broadly divided in two main parts. The first consisted of a two week stay in the city of Athens (the capital of Greece). The main goal was to meet with a number of public officials that held positions relevant to wildfire protection and mitigation in order to seek their assistance in framing the fieldwork methodology and strengthening the research question. The second part of the fieldwork included a 10 week trip around the state of Elia, located in the prefecture of Peloponissos. Elia was selected since it was the state most heavily affected by the wildfires in the entire country, as analyzed in Chapter 2. The objective of the fieldwork was to gather information regarding the wildfires from a satisfactory sample of villages within the state. The information would then be used in combination with secondary data in order to estimate an econometric model that would explain damage sustained due to wildfires. The methodology used for primary data gathering included a series of semi-structured interviews with people living in the villages, on-site observations as well as meetings with local officials.

3.4.1 Meetings in Athens

While in Athens a series of meetings were held with officials in the following organizations: the Geographical Service of the Hellenic Army, the Hellenic Fire Brigade, the National Institute of Agricultural Research, the General Secretariat of Civil Protection, the European Institute of Law, Science and Technology as well as various reporters in TV and radio stations[6].

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6 The author would like to thank Dr. Labros Liakopoulos (Cornel at the Geographical Service of the Hellenic Army), Dr. Gavriil Xanthopoulos (forester specialized in Forest Fire Science, and researcher at the Forest Research Institute of Athens), Mr. Foivos Theodorou (Director of Emergency planning and mitigation department in the General Secretariat

After those meetings it became apparent that the fieldwork would be greatly facilitated by the use of Google Earth (an internet based geographic application). Reliance on this free web-based application for access to satellite images before the wildfires of August, seemed the only possible alternative since access to other satellite imagery sources proved both cumbersome and financially out of reach.

3.4.2 A brief discussion of the use of Google Earth

There are several different types of satellite image resolutions on Google Earth ranging from 15cm all the way to 500m. However, most satellite images have a resolution of 15 meters. The higher the resolution the better the quality of the image. In high resolution images we are able to distinguish houses and individual plots of land. In lower resolution images such a distinction is not visible. Figure 3.1 on the following page illustrates the differences between a high and low resolution image on Google Earth.

The expectation was that the fieldwork would be greatly facilitated if the sample of villages was drawn from settlements that lay predominantly within the high resolution layer of Google Earth. That is because it would be easier for local people to identify burned property (i.e. houses, agricultural plots, etc.) on a detailed map during the interviews.

In addition a high resolution visual aid was more likely to attract the participant's attention and increase his willingness to engage in a conversation regarding the behavior of the fire. In the absence such a "tool" the next alternative for identifying burned

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of Civil Protection), Dr. Dionisia-Isidora Avgerinopoulou (President of the European Institute of Law Science and Technology), Dr. Argiro Filolia (Professor at the Fire Academy of Greece), Mr. Georgios Kapakis (Major of the Hellenic Fire Brigade), Mr. Georgios Keramitsoglou (reporter of Skai TV/radio).

property as well as key points in the path of the blazes would be to have locals physically lead the researcher to the places of interest and using a Global Positioning System (GPS) device to obtain the geographical coordinates of these locations. While that was indeed useful in most cases so that a first hand impression (as well as important photographic material) of the damage could be obtained it would prove highly inefficient. In addition the time that the researcher could spend observing burned property on the field was highly dependent on the time availability and willingness of the local people to engage in the process.

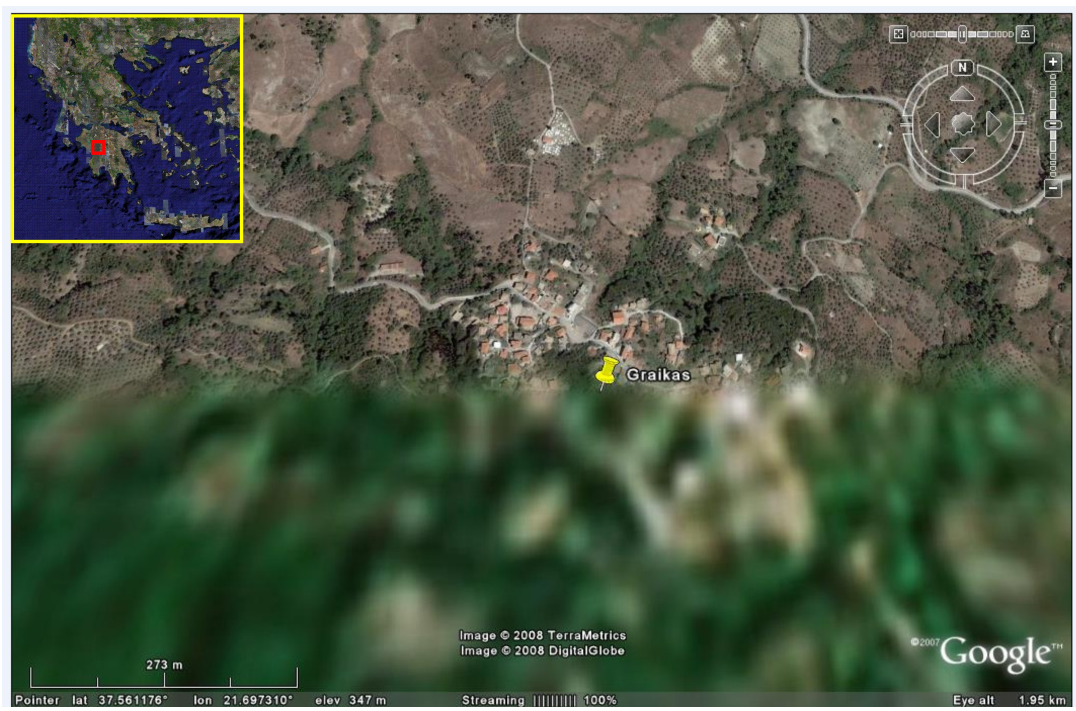

Figure 3.1: The Greek village of Graikas "cut" in half. Part of the village is illustrated on a high resolution image (houses and agricultural plots are visible) and part of it in a low resolution image (no infrastructure is visible). Source: GoogleEarth.com

On-site observations could not always be materialized. After the first few days on the field (i.e. the villages) it became apparent that a mixture of both methods should be used. That is, an attempt to get out on the field for a brief amount of time (in order to inspect burned infrastructure) while spending most of the time going over the Google Earth maps with the survey participants[7].

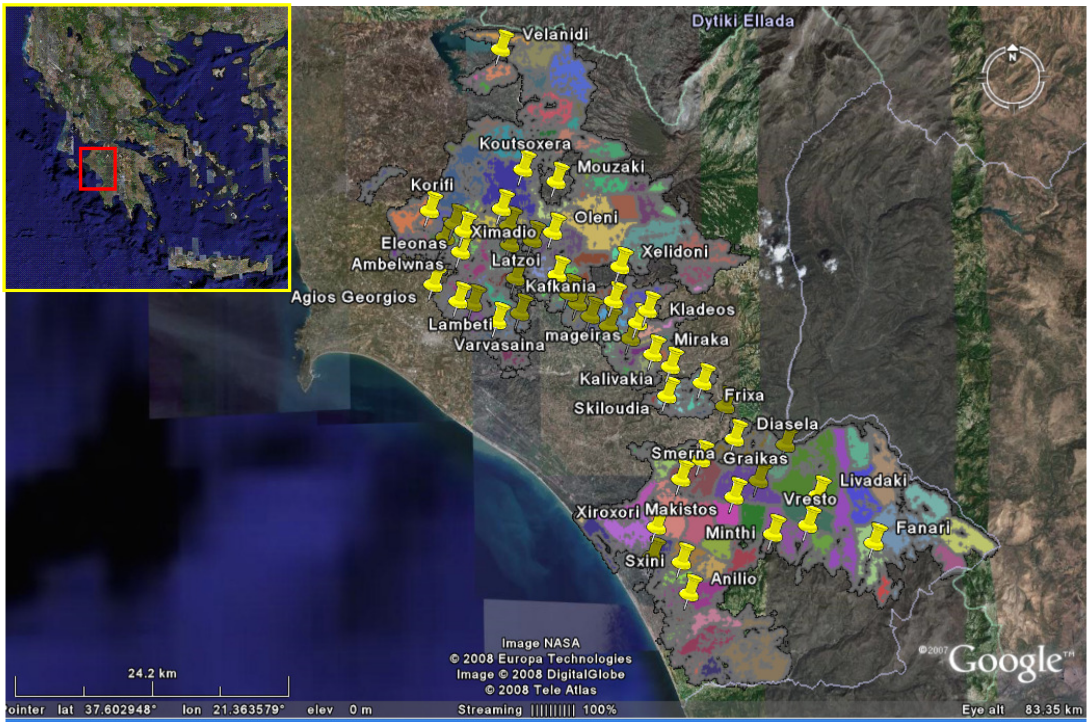

Figure 3.2: The colored segments of the map represent the burned areas of the state of Elia. The yellow pins represent villages sampled.

For the reasons highlighted above the villages sampled were chosen among those that were placed within the high resolution layer of Google Earth. Figure 3.2 illustrates the burned areas of the state of Elia as well as the location of the sampled villages, in an attempt to make the reader familiar with the geography of the region.

7 Google Earth is an internet based service. Given that in most of the settlements surveyed internet availability was limited, it was decided instead to use printed snapshots of Google Earth maps. Approximately 12 maps were needed, in order to effectively cover the area within and around a settlement. However, once on the field it was realized that even without internet connectivity Google Earth was still functioning. However, one could have access only to the areas that were previously viewed during an on-line session.

3.4.3 Getting on the field

After completing the first segment of the fieldwork (i.e. the various interviews with officials in Athens), the second part of the research began. The main objective in this case was to survey within a period of 10 weeks a minimum of 40 villages that were affected by the wildfires. Through a series of semi-structured interviews it was anticipated that the following pieces of information would be gathered:

1) Day and time that the fire arrived in the village.
2) Whether there was an order to evacuate the village (i.e. by the police or the fire department).
3) Whether people did evacuate or whether they decided to stay and engage in fire suppression effort.
4) Whether there was an electrical black out during the fire.
5) Whether water was available during the fire.
6) Level of damage that the village had sustained (i.e. number of burned houses, agricultural fields).
7) Information regarding the wildfire history of the village (i.e. how many times had the village burned during the past 30 years).
8) Deployment of fire fighting forces in the village (i.e. number of fire crews and/or operation of waterbombers).
9) What type (if any) of fire prevention management was being implemented in the area during the months before the high risk fire season?

The residents of the sampled villages had lived through a devastating destruction. They had lost friends and relatives, their houses and property were burned and in many cases they had received promises of financial support from the federal and state administration that were often not materialized. As one would imagine many of these people felt frustrated, angry and in some cases desperate. So, approaching them randomly and starting to ask questions regarding the wildfires was not really an option. That was something that quickly became evident to the researcher once on the field. The solution, in terms of finding an effective way to approach potential survey participants, was revealed through the administrative hierarchy of the state. Elia is divided into 22 counties. Each county is further divided into villages (on average 10 villages per county). Each village has an elected president whose main duty is to represent his electorate in the county meetings. The contact information of the presidents of the villages was readily available to the public, through the county headquarters. The procedure used in order to ensure the effective participation of individuals in the survey was the following. Initially the researcher would contact the president of the candidate village (i.e. the village that was to be surveyed) by phone. During this first approach the researcher would explain to the president who he was, what he was working on and would ask to meet with him in order to discuss several issues surrounding the wildfires. In most cases the meeting was arranged within the same day. The venue of the meeting is of particular importance and deserves to be analyzed to a certain extent. Most of the villages in the state of Elia are relatively small settlements whose population ranges between 100-500 people. Each village has at least one cafeteria (the Greek term is "kafeneio") which would be the equivalent of a pub where locals gather in the evening. This cafeteria is the meeting point of the male population in the village. Figure 3.3 illustrates the cafeteria of the village of Anilio during it's "peak" time (i.e. late afternoon).

Figure 3.3: The cafeteria of the village of Anilio. (Source: Dionysia Alexiadi).

The various cafeterias in the villages were the ideal location to host meetings with the various village presidents for several reasons. Once the researcher was seen in the cafeteria next to president, he immediately received some sort of "social clearance" (i.e. he was seen next someone that the locals knew, and most probably trusted). Immediately that would generate some interest from the people in the cafeteria. Very soon many villagers would join in the conversation between the researcher and the village president and seek to have their views recorded for the purposes of the research. Essentially, in most cases the interview did not just include one person (i.e. the village president), but 5, 10 or in some cases the entire male population of the village[8].

8 Initially, the researcher had to clarify two things; that he was neither a journalist nor a public servant. As soon as it was clear to all the locals that the researcher was a Greek student doing his master's at a university in the USA everyone became egger to share their experiences from the days of the wildfires.

The length of the interviews would range from 15 minutes to 2 or even 3 hours in some cases. Usually, given that most people had to work during the day, the only time available for them to participate in the survey was late afternoon (i.e. after 4 or 5pm). By the time the interview was over the participants were asked to show the researcher some of the burned property (i.e. houses and/or agricultural fields). However, that was not always feasible due to the following reasons: 1) it was already dark by the time the interview was over, or 2) because the survey participants were not motivated enough to engage in such a process. Table 3.1 below provides an analysis of the main information regarding the village interviews. Overall, 206 people participated in the survey (approximately 4 people per village) while total time spent on interviews was 2,594 minutes (i.e. 43 hours-approximately 52 minutes per village) and actual on-site (field) observations were made in 55% of the entire sample (27 out of 49 villages).

3.5 Conclusion

The aim of the project is to model fire spread and intensity by incorporating a series of human related variables not commonly found in previous literature, as well as the more conventional ecological variables. Primary data were gathered through a 10 week long field research in the state of Elia. In total 49 villages were surveyed. It is important to note that sample selection was limited to villages that were affected by the fire and were within the high resolution layer of the Google Earth web-application. The data gathering methodology consisted of semi-structured interviews with citizens of the sampled villages. The following chapter presents both primary and secondary data and sets the scene for the econometric estimation.

Table 3.1: Summary of village interview information

Village name	Popu lation	Survey participants	Interview length (in minutes)	Field observ ations	Village name	Popu lation	Survey particip ants	Interview length (in minutes)	Field observ ations
Vroxitsa	439	4	180	Yes	Anilio	134	1	37	Yes
Agioi Apostoloi	111	5	30	Yes	Makistos	68	3	17	Yes
Korifi	303	2	25	No	Minthi	201	1	34	No
Lantzoi	829	7	100	Yes	Smerna	311	3	113	Yes
Xaria	234	12	45	No	Zacharo	6.492	5	25	Yes
Sopi	303	7	53	No	Sxinoi	648	2	128	Yes
Xeimadio	645	35	42	No	Diasella	685	1	18	No
Karatoulas	952	2	12	No	Kalivakia	494	1	16	No
Koutsoxera	688	4	32	No	Ploutoxori	338	9	189	Yes
Mouzaki	432	1	16	No	Skiloudia	542	3	46	Yes
Oleni	696	1	22	No	Tripiti	587	3	61	Yes
Agios Georgios	709	1	10	Yes	Platiana	578	1	31	No
Ambelonas	730	1	48	Yes	Graikas	412	8	140	Yes
Eleonas	497	3	29	No	Livadaki	331	1	19	Yes
Koliri	1.058	7	78	Yes	Vresto	432	4	19	No
Lambeti	978	2	72	Yes	Fanari	206	2	17	No
Miraka	379	4	47	Yes	Parapougi	69	5	55	Yes
Kafkania	189	2	88	Yes	Velanidi	309	7	43	Yes
Kladeos	162	18	95	Yes	Xiroxori	201	1	34	No
Koskinas	241	3	75	No	Lanthoi	549	6	92	Yes
Mageiras	127	1	35	No	Varvasaina	1.293	5	42	Yes
Pelopio	1.061	1	38	Yes	Frixa	484	1	23	No
Platanos	1.353	4	87	Yes	Palaiovarvasaina	452	1	45	No
Pournari	261	2	33	No	Irakleia	368	2	39	Yes
Xelidoni	646	1	20	No					

CHAPTER 4

DATA ANALYSIS

4.1 Introduction

The basis of this study is the analysis of field and secondary data sources in an attempt to determine the relative importance of different variables in the damage done by the fire.. Each of the variables will be presented and analyzed in the current chapter. The main goal is to explore the relationship of the dependent variable with each of the right hand side (RHS) variables, as well as the relationships amongst RHS variables themselves. We shall begin with the presentation of the dependent variable.

4.2 Dependent variable

The ultimate goal of the proposed model (originally presented in chapter 3) is to identify the factors that played a key role in the damage that the fire caused to the various villages. The dependent variable of the model is the percentage of the area of a village that was burned.

Each village has a set of administrative boundaries that can be identified in digital form. The boundaries of the sampled villages are illustrated in figure 4.1.With the use of GIS software we were able to calculate the exact area of each settlement, based on the administrative boundaries pictured in figure 4.1. On average, each of the 49 villages sampled cover an area of 9.8 km^2 (as indicated in table 4.1).

Table 4.1: Summary statistics of total area for the sampled villages.

Variable	Observations	Mean	Median	Std. Error	Min	Max
Total area in (in km^2)	49	9.856	9.025	5.176	3.039	26.300

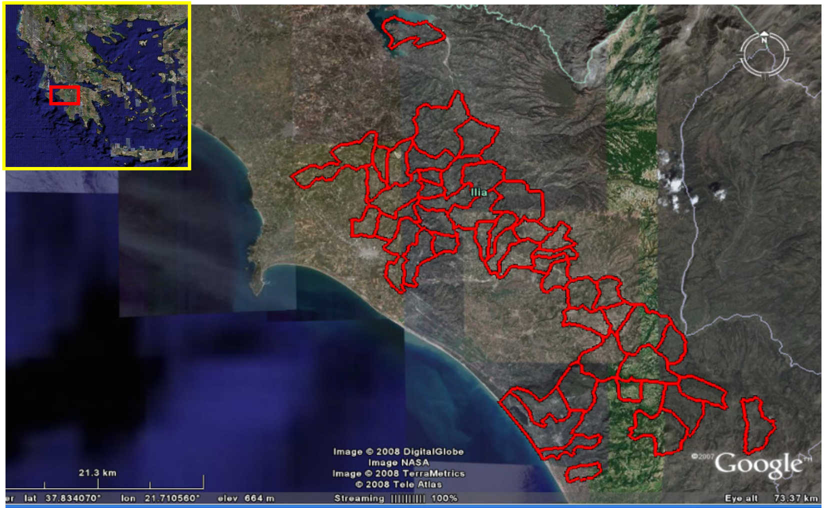

Figure 4.1: Administrative boundaries of the 49 sampled villages (highlighted in red).

Using a series of satellite images (such as the one illustrated in figure 4.2) it became possible to distinguish the burned areas in the regions of interest.

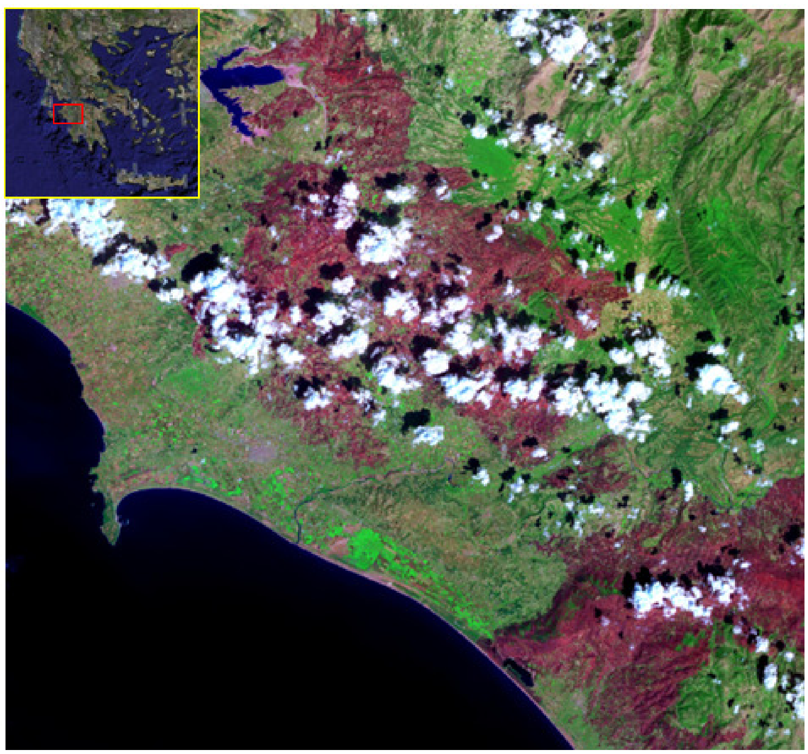

Figure 4.2: Satellite image illustrating burned segments of land in the state of Elia. Burned segments have a red color. Source: NASA (2007)

With the appropriate digital manipulation we were able to extract a layer depicting the burned areas of the sampled villages. The latter is illustrated in figure 4.3.

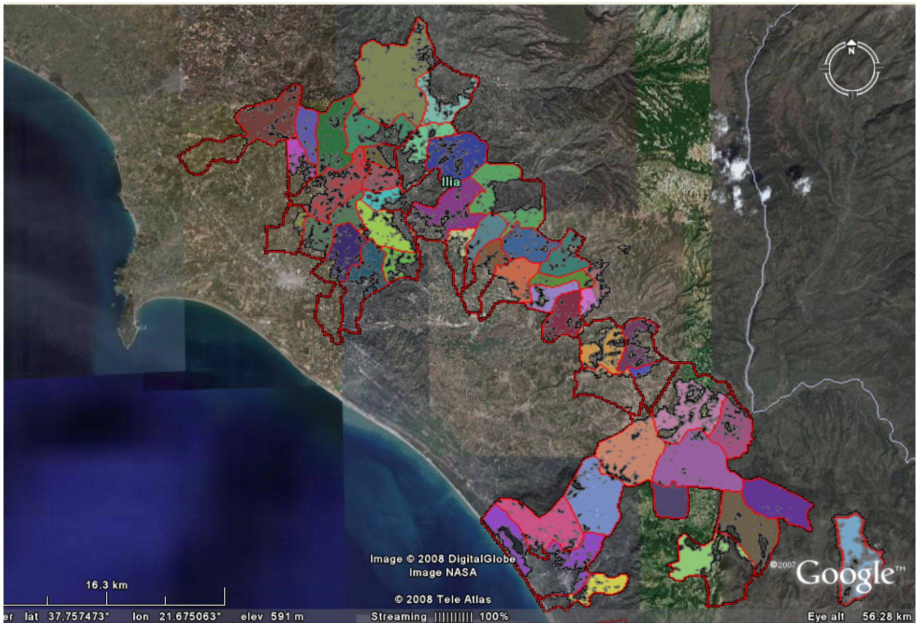

Figure 4.3: Burned areas in sampled villages represented by the colored segments. Each color depicts a different village. Red lines depict the administrative boundaries of the villages.

This layer was then used for the calculation of the exact area of burned land within the boundaries of the various settlements. On average, each of the 49 observations within the sample had a burned area of approximately 5.8 square kilometers, as illustrated in table 4.2.

Table 4.2: Summary statistics of area burned for the sampled villages.

Variable	Observations	Mean	Median	Std. Error	Min	Max
Burned area (in km^2)	49	5.84	4.83	4.32	0.39	23.01

Nevertheless, this number could potentially include a certain amount of error, due to the method that was utilized for its calculation. To illustrate the above point we will present the case of a specific village; that of Kalivakia, in the county of Skilloudia.

Figure 4.4 presents the administrative bounders (outlined in green) as well as the layer of burned land (highlighted in red) for the village of Kalivakia. The blue rectangle identifies the magnified segment that is more closely illustrated in figure 4.5.

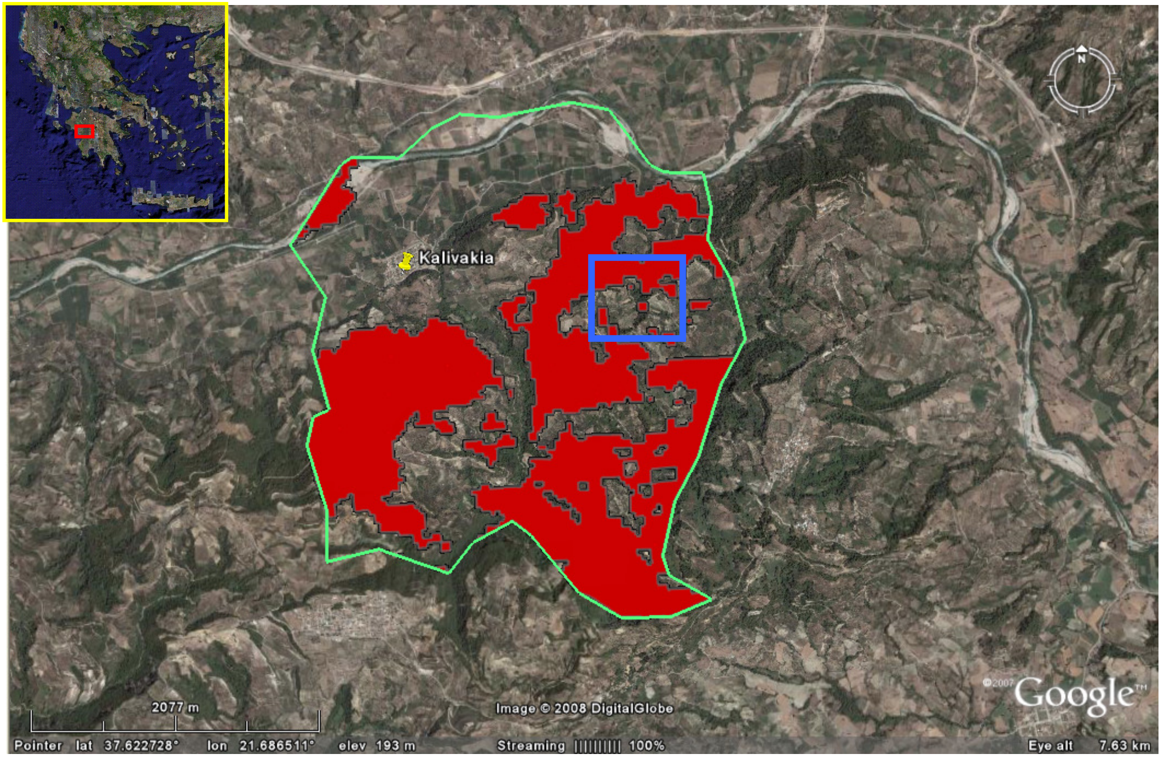

Figure 4.4: The village of Kalivakia.

The layer of burned land (illustrated in red in figure 4.4) is comprised of thousands of individual pixels (such as the one magnified in the green rectangle of figure 4.5), each one covering an area of 10,000 square feet (i.e. 100 feet by 100 feet). From each pixel we are able to extract one piece of information; whether the area covered by the pixel is burned or not. For example, if 2/3 of a pixel include area burned (while the remaining 1/3 depicts non-burned land) the Arc View software that is used for the process would yield as a result the information that the entire pixel is burned (as is the case for the magnified pixel on figure 4.5). However, in that way we are introducing a certain amount of error in the calculation of burned land, since we are failing to identify correctly burned vs non-burned area. For example, in the case presented above we would be failing to realize the fact that 1/3 of our "burned" pixel is actually not burned.

Nevertheless, we assume that on average the amount of error is not statistically significant. We expect, that is, that the burned vs non-burned segments that we would fail to identify would overall even out.

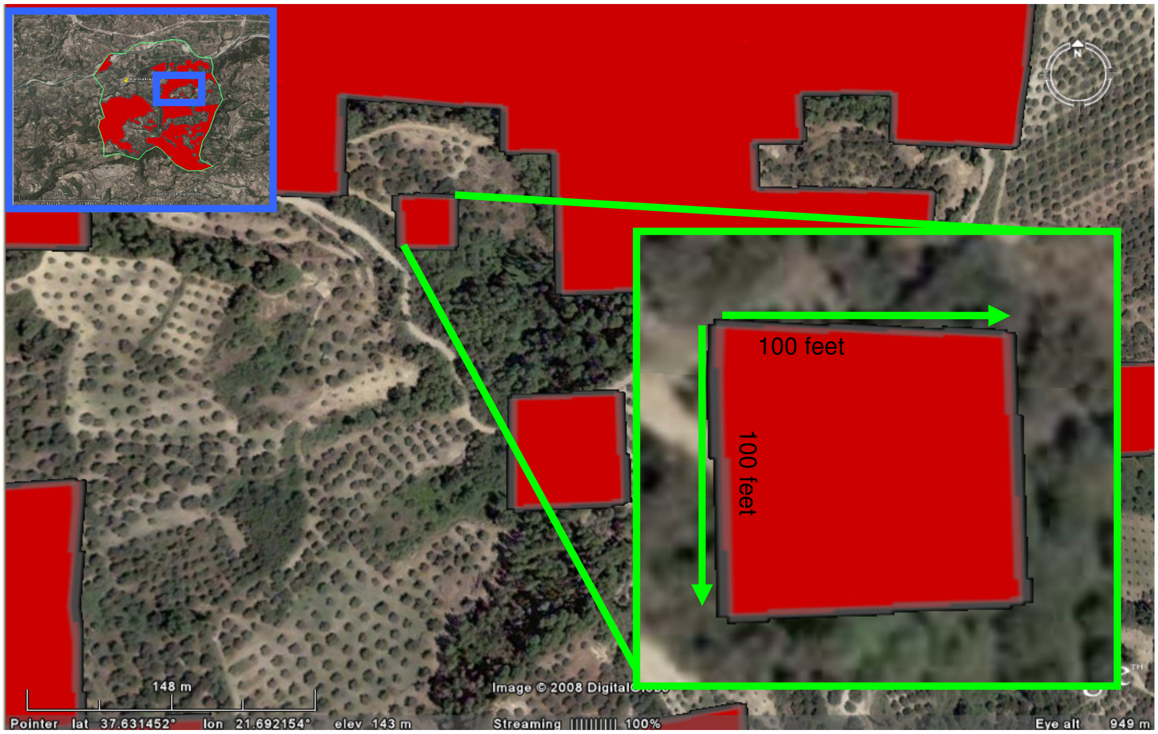

Figure 4.5: The magnified segment of the blue rectangle of figure 4.4.

Finally, by adding the areas of all the pixels representing burned land within the administrative boundaries of a village, we are able to obtain the total burned area for a specific settlement.

The dependent variable of the model (i.e. percentage of area burned) will be then calculated using the following formula.

$$percent\_area\_burned = \frac{burned\_area}{total\_area}$$

Table 4.4 (on page 43) summarizes the information on total as well as burned areas for the sample. In addition it provides a column with the dependent variable. In an attempt to make table 4.4 easier to interpret, we have categorized the percent of burned areas into 4 groups:

1) category “0” for percentages of area burned between 0-25%

2) category “1” for percentages of area burned between 25-50%

3) category “2” for percentages of area burned between 50-75%

4) category “3” for percentages of area burned between 75-100%

The aggregate information on percentage of area burned based on the above categories is illustrated in table 4.3.

Table 4.3: Aggregate percentage of area burned. Percentage of villages in each of the four categories in parenthesis.

Percentage of area burned in categories	Villages
0-25%	4(8%)
25-50%	15(31%)
50-75%	12(24%)
75-100%	18(37%)

By observing table 4.3 one could argue that category “0” (i.e. villages with a percentage of area burned between 0% and 25%) is under sampled. The reason for which this category includes a low number of villages has to do with the practicalities of the interviewing process. In villages that had sustained few damages, people were rather reluctant to talk about the fires. In addition the quality of information that they would provide was not always reliable, since the small level of damage usually meant a low level of engagement on their part. As a result our analysis is conditional on there being a significant amount of damage done by the wildfire.

Table 4.4: Total area, burned area and proportion of area burned for the sampled villages. Areas are in square meters.

Village	Total area (in square meters)	Burned area (in square meters)	Percent burned	Village	Total area (in square meters)	Burned area (in square meters)	Percent burned
Agioi Apostoloi	4,403,999	4,074,500.86	0.92518	Miraka	6,473,430.07	4,994,546.91	0.77155
Agios Gevrgios	6,444,213	597,533.55	0.09272	Mouzaki	11,426,635.85	4,165,836.42	0.36457
Ampelonas	12,477,263	6,715,116.92	0.53819	Oleni	10,985,150.32	8,637,978.20	0.78633
Anilio	4,705,049	1,906,472.77	0.40520	Palaiovarvasaina	4,838,060.37	2,213,456.92	0.45751
Diasella	19,015,643	8,393,416.34	0.44140	Parapougi	3,720,314.45	389,520.88	0.10470
Elaionas	9,720,047	8,128,539.78	0.83627	Pelopion	7,174,573.17	2,457,510.89	0.34253
Fanari	10,550,783	8,132,210.23	0.77077	Platanos	9,313,118.94	4,600,097.90	0.49394
Frixa	7,467,172	3,716,384.37	0.49770	Platiana	16,682,767.19	16,033,732.21	0.96110
Graikas	15,295,499	12,936,772.35	0.84579	Ploutohori	6,285,878.40	842,522.23	0.13403
Irakleia	5,246,939	1,455,088.77	0.27732	Poyrnario	5,614,457.48	4,059,632.60	0.72307
Kafkania	6,700,712	5,662,558.05	0.84507	Skillountia	9,506,445.24	702,181.32	0.07386
Kalivakia	9,318,320	4,038,098.95	0.43335	Smerna	14,466,233.65	13,265,235.05	0.91698
Karatoulas	8,691,031	3,763,523.49	0.43304	Sopion	3,039,390.23	1,177,161.04	0.38730
Kladeos	5,897,817	4,598,379.29	0.77967	Sxinoi	6,310,286.37	3,370,184.59	0.53408
Koliri	13,863,455	5,222,966.06	0.37674	Triphti	8,433,207.55	6,544,262.89	0.77601
Korifi	18,332,283	8,994,701.25	0.49065	Varbasaina	10,784,979.22	4,071,257.44	0.37749
Koskinas	4,053,854	3,235,353.09	0.79809	Velanidi	12,042,366.11	3,251,687.31	0.27002
Koutsoxera	26,336,416	23,014,752.01	0.87388	Vresto	12,186,023.23	9,578,032.91	0.78599
Lambeti	8,823,934	5,231,291.31	0.59285	Vroxitsa	5,112,148.03	2,060,787.12	0.40312
Lanthi	8,901,852	5,682,630.42	0.63836	Xaria	3,836,941.63	2,642,058.06	0.68858
Latzoi	13,008,814	8,130,858.44	0.62503	Xeimadio	9,025,275.36	5,718,515.06	0.63361
Libadaki	9,606,000	9,552,822.56	0.99446	Xelidoni	16,758,550.66	8,853,453.68	0.52829
Mageiras	3,267,317	2,883,487.91	0.88252	Xiroxori	13,268,605.01	11,278,577.96	0.85002
Makistos	4,883,406	4,832,033.45	0.98948	Zacharo	22,065,860.74	9,171,663.32	0.41565
Minthi	16,596,073	5,314,826.28	0.32025				

Figure 4.6 illustrates a frequency histogram with the distribution of the dependent variable (i.e. the percentage of area burned for the 49 sampled villages).

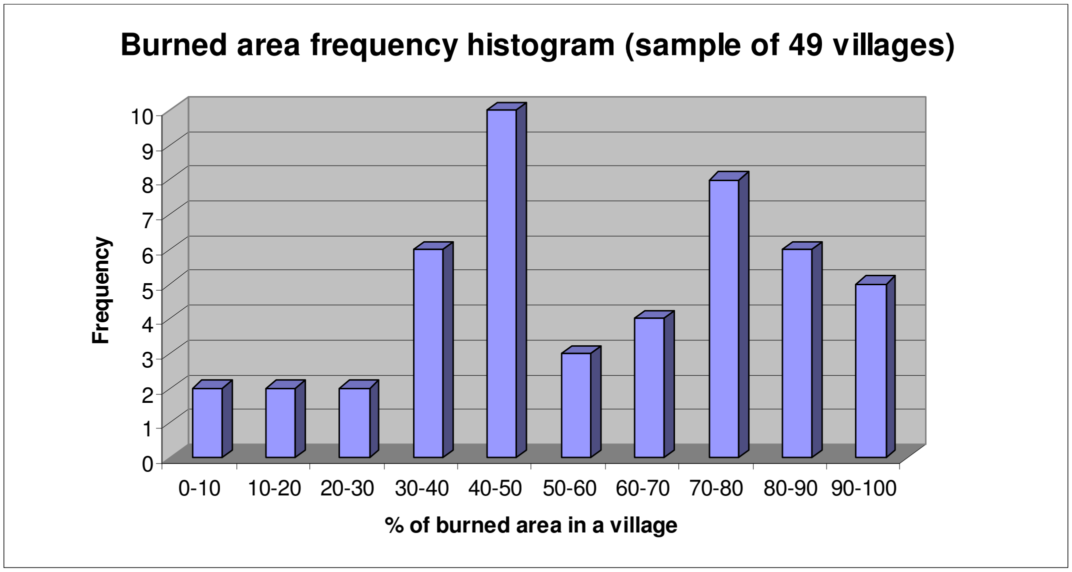

Figure 4.6: Burned area frequency histogram for the sampled villages.

Figure 4.7 illustrates the frequency histogram of the percentage of area burned for all the 130 villages of the state of Elia that were affected by the fire.

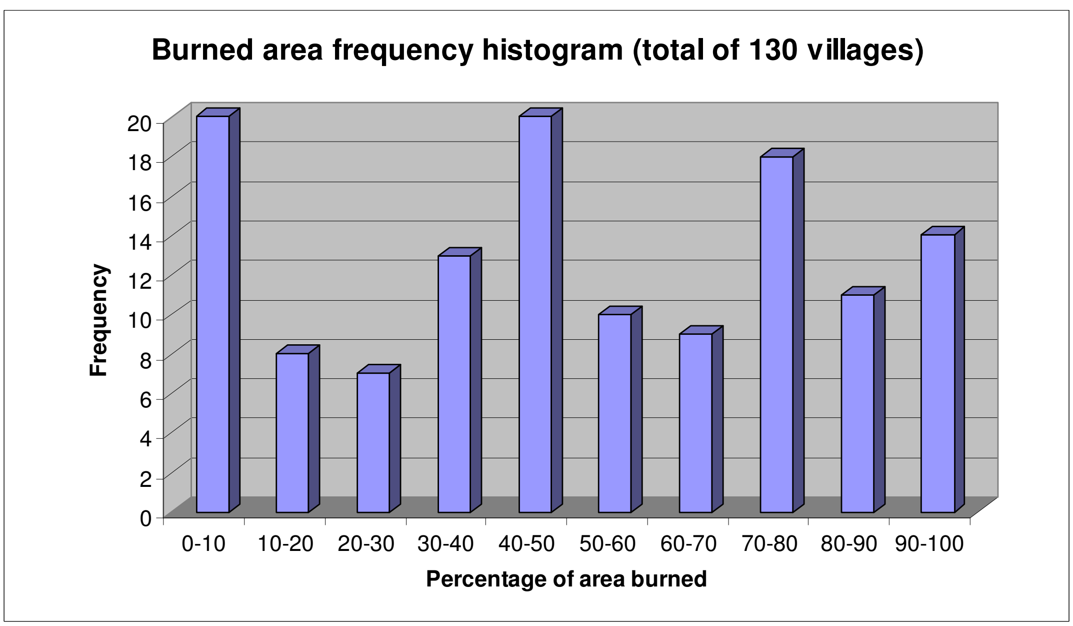

Figure 4.7: Burned area frequency histogram for all the villages in Elia that were affected by the blazes.

By comparing the two figures one can draw the conclusion that although certainly not normally distributed, the two histograms look rather similar. Hence, if we assume that figure 4.7 presents the distribution of the dependent variable in the parent population (i.e. all the villages of the state that were affected by the fire) and figure 4.6 the distribution in the sample, then our sample could be characterized as representative of the population. However, the first class (i.e. villages that had a percent of area burned between 0-10%) are certainly under sampled for the reasons identified earlier. To address this issue our analysis in chapter 5 uses a truncated regression model[9].

[9] Note that the majority of the current chapters' content is drawn from the semi-structured interviews conducted either with state officials or with village citizens. In the event where information drawn from interviews with village citizens is used the bibliographical information in the text will be indicated as follows: (Field interviews, 2008). Unless otherwise indicated tables in chapter 4 are constructed using the information that was drawn from field interviews.

4.3 Explanatory variables

In the following section we focus on presenting the independent variables that will be used in the model. We will be using both secondary data as well as information gathered on the field. Explanatory variables can be broadly classified into five different categories:

1) field data
2) meteorological data
3) topographical data
4) demographical data
5) vegetation data

4.3.1 Field data

Field data where gathered using the series of semi-structured interviews, the methodology and technicalities of which were presented in chapter 3. Table 4.5 provides brief a descriptive analysis of the field data.

Table 4.5: List of field data.

Variable name	Categories
Day the fire reached a village	24th, 25th, 26th or 27th of August 2008
Order to evacuate the village	Evacuation or no evacuation
Participation of the locals in fire suppression	Low, medium or high participation
Operation of fire planes	None, low or high level of operation
Presence of fire crews	None, low or high presence
Availability of water	Low, medium or full availability
Fire history of the village	Four categories formed based on the last time a village had sustained a wildfire.
Fire prevention	No prevention, low or high prevention

4.3.1.1 Day-Evacuation-Participation

The first three independent variables will be presented in the same section since, to a certain extent, they are related to one another. Perhaps the most important piece of information is the day at which the fire arrived at each village.

The blazes that affected the region of the sampled villages lasted during a 5 day period between August 24th through 28th. The fires were so massive and the need for the intervention of the Fire Brigade so great that fire crews were not able to keep track of and record the starting times of most blazes, beyond those that appeared during the first day (i.e. August 24th). The official records of the Fire Department of the city of Pirgos (the capital city of the state of Elia) included documentation only for the 6 initial blazes of 24th of August (Georgiopoulos, 2008). These are illustrated in figure 4.8.

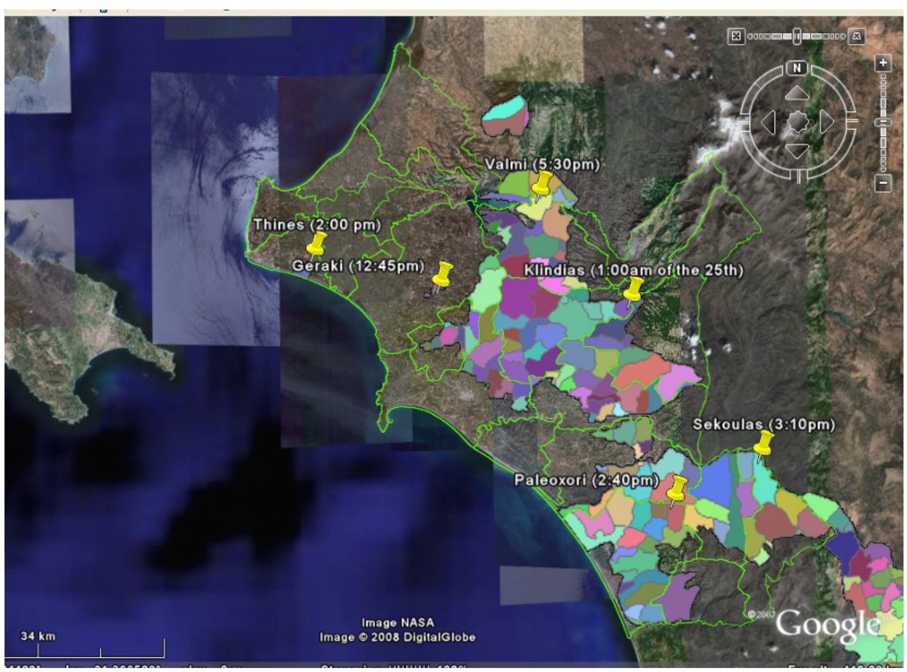

Figure 4.8: The 6 initial blazes of August 24th and their respective times of occurrence. Blazes are presented by yellow pins (the fire of Klindias occurred at 1:00 am on August 25th). Colored segments of the map represent areas burned. Two of the six blazes (Thines and Amaliada at the North-West of the region) were successfully contained. The other four burned almost uncontrollable for a period of 5 days.

After those 6 initial blazes the Fire Brigade could not keep track of the new blazes that occurred (if any). As the fires spread and reached more and more villages firefighters would respond based on the level of threat perceived.

4.3.1.2 The importance of the first day of the fires – The tragic incident of Artemida

One of the 6 initial blazes occurred on August 24th at 2:40 pm at the settlement of Paleohori (see figure 4.8 for the geographical location of the settlement). Paleohori as well as the adjacent villages of Artemida and Makistos are located on a mountainous landscape with very narrow roads. Tall blazes, in combination with strong winds and extremely low levels of relative humidity led the locals to spontaneously evacuate the villages. A big convoy of cars with people seeking shelter at the nearby beach, located just a few kilometers away, was coming down the road illustrated in figure 4.9 (Field interviews, 2008).

At point 1 (illustrated on figure 4.9) a fire truck coming up the road and heading towards the villages crashed against incoming traffic. That accident blocked the road and people were trapped on the spot. Very soon the fire reached the location of the accident burning 9 people (3 seasonal firemen and 6 citizens) at approximately 3:30 pm (Nodaros, 2007). This tragic incident was of paramount importance in the course of the 5-day wildfire crisis-period. Very soon the news was broadcasted all over the state. It was the first time in the nation’s contemporary history that so many people had died in a wildfire.

Figure 4.9: The road leading from the villages of Makistos and Artemida to the beach of Zacharo.

The incident caused a great deal of panic in Elia. From that day onward, whenever a fire approached a village, authorities (predominantly the Police and in some cases the Fire Department) would order the evacuation of the settlement, in some cases, even if there was no immediate danger (Field interviews, 2008). Faced with an unprecedented national tragedy the federal authorities decided that their first priority should be to protect human lives by making sure that citizens were transported away from villages that were close to the blazes.

What foresters and fire scientists claimed should have been done, however, was for authorities to have summoned capable villagers that could provide significant assistance to the efforts of firefighters (Xanthopoulos, 2007b). As the days went on both citizens and officials started realizing that local villagers (predominantly farmers by occupation) were a rather effective fire suppression force given the equipment and experience they had in combating blazes. Most of these people had fought wildfires in the past and possessed farmer's trucks as well as water tanks that could be used as "mini-fire-trucks" (such as the one illustrated in figure 4.10). As a result evacuation orders would decrease after the 3 day (i.e. August 26th) and people would start realizing that engaging in fire suppression efforts was an effective way of protecting themselves and their property (Field interviews, 2008).

Figure 4.10: A farmer's truck participating in fire suppression efforts. Source: www.youtube .com (2008)

It is interesting to note that the Greek General Secretariat of Civil Protection advices civilians living in the Wildland Urban Interface (WUI), not to evacuate their homes unless their escape route is guaranteed (General Secretariat of Civil Protection, 2007). Note that houses in Greece are build out of strong/inflamable materials (i.e. cement and bricks) due to the need to sustain the frequent earthquakes that take place all around the country. As a result people are more likely to survive by staying close to a relatively inflammable construction than by driving through the woods. However, the fact that the predominant strategy during the first two days of the wildfires was to order the evacuation of settlements is indicative of the panic that was prevalent in Elia. Table 4.6 provides a detailed account of the day the fire reached each sampled village, whether or not there was an order to evacuate and finally presents an index regarding the level of participation in fire suppression by the villagers.

As far as the latter variable is concerned (i.e. level of participation), several factors were taken into consideration for the construction of the 3 categories ("low", "medium" and "high"). These were the following:

1) Number and age of the people that participated in fire suppression effort.
2) Available equipment (i.e. farm tractors, water sprinkler mechanisms, etc.)
3) Effectiveness of the effort (i.e. were the people able to save property from being burned).

For example, in the case of the village of Pournari (ID#35 on table 4.6) evacuation orders were issued by the authorities and very few people remained in the settlement. They were unable to fight the fire though due to the lack of available equipment. Several houses and agricultural warehouses were burned. As a result Pournari was classified as having "low participation". On the other hand in the village of Kladeos (ID#14 on table 4.6) most citizens actively engaged in fire mitigation efforts using their agricultural equipment, ignoring evacuation orders. They were able to save houses from being burned and hence the Kladeos was characterized as having "high participation".

Table 4.6: Detailed presentation of the day the fire reached a village, whether there was an order to evacuate as well as the level of participation in fire suppression by the locals.

Villages	Participation of the villagers in fire suppression	Day that the fire reached the village	Ordered evacuation	Villages	Participation of the villagers in fire suppression	Day that the fire reached the village	Ordered evacuation
Agioi Apostoloi	medium	25th	yes	**Minthi**	medium	24th	yes
Agios Georgios	high	26th	no	**Miraka**	medium	26th	yes
Ambelonas	medium	25th	yes	**Mouzaki**	high	25th	yes
Anilio	low	24th	yes	**Oleni**	high	25th	yes
Diasella	high	25th	no	**Palaiovarvasaina**	high	25th	no
Eleonas	medium	25th	yes	**Parapougi**	medium	25th	yes
Fanari	medium	25th	yes	**Pelopio**	high	26th	no
Frixa	medium	27th	yes	**Platanos**	medium	26th	yes
Graikas	medium	25th	yes	**Platiana**	medium	25th	yes
Irakleia	high	25th	yes	**Ploutoxori**	high	27th	no
Kafkania	medium	26th	yes	**Pournari**	low	25th	yes
Kalivakia	high	26th	no	**Skiloudia**	high	26th	no
Karatoulas	medium	25th	yes	**Smerna**	low	24th	yes
Kladeos	high	26th	yes	**Sopi**	high	25th	yes
Koliri	medium	26th	no	**Sxinoi**	low	24th	yes
Korifi	high	25th	yes	**Tripiti**	medium	25th	yes
Koskinas	low	26th	no	**Varvasaina**	medium	26th	yes
Koutsoxera	high	25th	yes	**Velanidi**	low	25th	yes
Lambeti	high	26th	no	**Vresto**	low	24th	yes
Lanthoi	high	26th	yes	**Vroxitsa**	medium	25th	yes
Lantzoi	medium	25th	yes	**Xaria**	high	26th	yes
Livadaki	low	24th	yes	**Xeimadio**	high	25th	yes
Mageiras	high	26th	yes	**Xelidoni**	high	25th	yes
Makistos	low	24th	yes	**Xiroxori**	low	24th	yes
				Zacharo	medium	24th	no

Tables 4.7-4.9 summarize the information provided on table 4.6. As can be observed from table 4.7, most of the sampled villages (i.e. 47%) were reached by the blazes during the second day of the crisis period.

Table 4.7: Days at which the blazes reached the sampled villages.

Day the fire reached the village	Number of villages	% of villages
24th	9	18%
25th	23	47%
26th	15	31%
27th	2	4%

Evacuations were ordered for the vast majority of the sampled villages (77%) as indicated in table 4.8. Only in 23% of the cases was there no such order.

Table 4.8: Order to evacuate a settlement.

Ordered evacuation	Number of villages	% of villages
No	11	23%
yes	38	77%

In some cases, villagers would not always follow evacuation orders, but instead decide to stay and engage in fire suppression efforts. Table 4.9 gives an indication of the participation of local people in firefighting.

Table 4.9: Participation of the locals in firefighting efforts.

Participation of villagers in fire suppression	Number of villages	% of villages
Low	10	20%
Medium	19	39%
High	20	41%

In order to explore the relationship between each of the three independent variables (i.e. day the fire arrived at a village, order to evacuate and participation of the locals in fire suppression) analysed in this section and the percent of area burned (i.e. the dependent variable of the model) a series of t-tests will be conducted. The results are provided in tables 4.10-4.13.

Table 4.10: Mean area burned (in percent), where villages are categorized based on the day that they were reached by the blazes.

Day the blazes reached a village	Observations	Mean area burned	Std. Error	Std. Dev.	95% Conf. Interval	
Day 1 (24th)	9	**0.6902345**	0.0902257	0.270	0.482	0.898
Day 2 (25th)	23	**0.5849196**	0.0492218	0.236	0.482	0.686
Day 3 (26th)	15	**0.5458213**	0.0670817	0.259	0.401	0.689
Day 4 (27th)	2	**0.315865**	0.181835	0.257	-1.994	2.626

As one can observe, the mean percent of area burned decreases from 69% (during the first day) to 54% (during the second), 54% (during the third) and finally 31% at day four. This is indicative of the severity of the blazes in day one. Note that differences in the percentages for the first 3 days are not statistically significant. The percentage for the fourth day is not credible due to the limited sample size of villages burned at that day.

Table 4.11: Mean area burned (in percent), where villages are categorized based on whether there was an order to evacuate or not.

Evacuation order	Observations	Mean area burned	Std. Error	Std. Dev.	95% Conf. Interval	
Evacuation was ordered	38	0.6401468	0.0380	0.234	0.563	0.717
No evacuation ordered	11	0.3780664	0.0655	0.217	0.232	0.524

Settlements where people were ordered to evacuate had a mean percent of area burned that was significantly greater than that of villages where no evacuation order was issued (i.e. 64% and 38% respectively; the difference is statistically significant at the 1% level). However, we cannot be sure which way the relationship runs in this case; that is, does the evacuation category have a higher percent of area burned because in those villages fewer (if any) people stayed to fight the blazes? Or is it that evacuations were ordered because a village was truly in great danger from the blazes (hence the higher percent of area burned)? Evidence from the field suggests that in some cases evacuations were not justified, but rather the result of poor coordination between the state and federal agencies as well as the panic that was prevalent in the state of Elia after the tragic incident of Artemida (presented in section 4.3.1.2). Table 4.12 further strengthens the above argument.

Table 4.12: Evacuations tabulated versus the day that the fire reached a settlement.

	Evacuation orders by day	
Days	**No order**	**Evacuation ordered**
Day 1(24th)	1(11%)	8 (89%)
Day 2(25th)	2(9%)	21(91%)
Day 3(26th)	7(47%)	8(53%)
Day 4(27th)	1(50%)	1(50%)

Police and Fire Department officials ordered the evacuation of the villages indiscriminately during the first day (i.e. after the tragic incident in Artemida) fearing a higher death toll (Field interviews, 2008). As seen in table 4.11 evacuation orders were given for 89% and 91% of the villages in days 1 and 2 respectively. However, in day 3 (August 26th) evacuation orders drop to 53%, presumably because the initial break down in the coordination of the state fire suppression organization was starting to get back on track.

Table 4.13: Mean area burned (in percent), where villages are categorized based on the level of participation in fire suppression by the locals.

Participation of villagers	Observations	Mean area burned	Std. Error	Std. Dev.	95% Conf. Interval	
Low participation	10	0.726739	0.078	0.247	0.549	0.903
Medium participation	19	0.5956626	0.055	0.241	0.479	0.712
High participation	20	0.4949665	0.054	0.243	0.381	0.608

It appears that participation played an important role at reducing the damage caused by the blazes (difference between “low” and “medium” category is significant at the 10% level. Difference between “medium” and “high” category is not significant (P-value=10.15). Table 4.13 suggests that the higher the level of participation, the lower the percent of area burned in the village. However, one could argue that a certain level of endogeneity exists in this case, since people’s propensity to participate in firefighting efforts could have been motivated by a series of factors. Geographical remoteness, social cohesion as well as climatic conditions could have all influenceed people's decision to engage in fire fighting.

An interesting point is that, as the days went on after the tragic incident of Artemida, villagers demonstrated an increasing propensity to engage in fire suppression efforts. Table 4.14 demonstrates the fact that, during the first day, there were very few cases of villagers participating in firefighting (a mere 22%). However, that figure increases sharply during the next two days (reaching 92% and 93% respectively). The information on Table 4.14 is also illustrated on Figure 4.11.

Table 4.14: Participation of villagers in fire fighting efforts by day.

	Participation of villagers in fire suppression		
	Low	Medium	High
Day 1(24th)	7 (78%)	2 (22%)	0
Day 2(25th)	2 (9%)	11(48%)	10 (43%)
Day 3(26th)	1 (7%)	5 (33%)	9 (60%)
Day 4(27th)	0	1 (50%)	1 (50%)

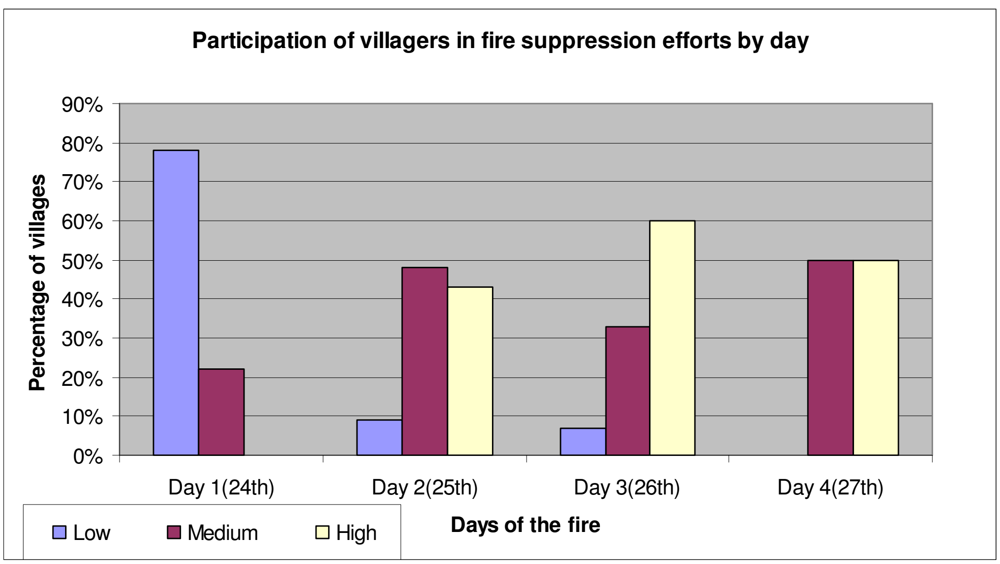

Figure 4.11: Bar chart illustrating the participation of villagers in fire suppression efforts by day.

4.3.1.3 Operation of fire crews and waterbombers

As stated in the previous chapter the responsibility for fire suppression lies within the jurisdiction of the Hellenic Fire Brigade. Fire prevention as well as post-fire management, on the other hand, are both handled by the Forest Service.

The state of Elia has 5 fire stations. Their locations (marked by yellow pins) and respective areas of responsibility (identified by different colours) are illustrated in figure 4.12. Each station is staffed by a combination of permanent and seasonal personnel. The latter consists of fire fighters working on 6-month long contracts that last from May 1st until October 31st. As of 2008 these contracts have been extended to 8 months (April 1st to November 31st) in an effort to provide seasonal fire fighters with a more stable source of income. Table 4.15 provides information on the personnel and automobile infrastructure capacity for each of the 5 fire stations in Elia.

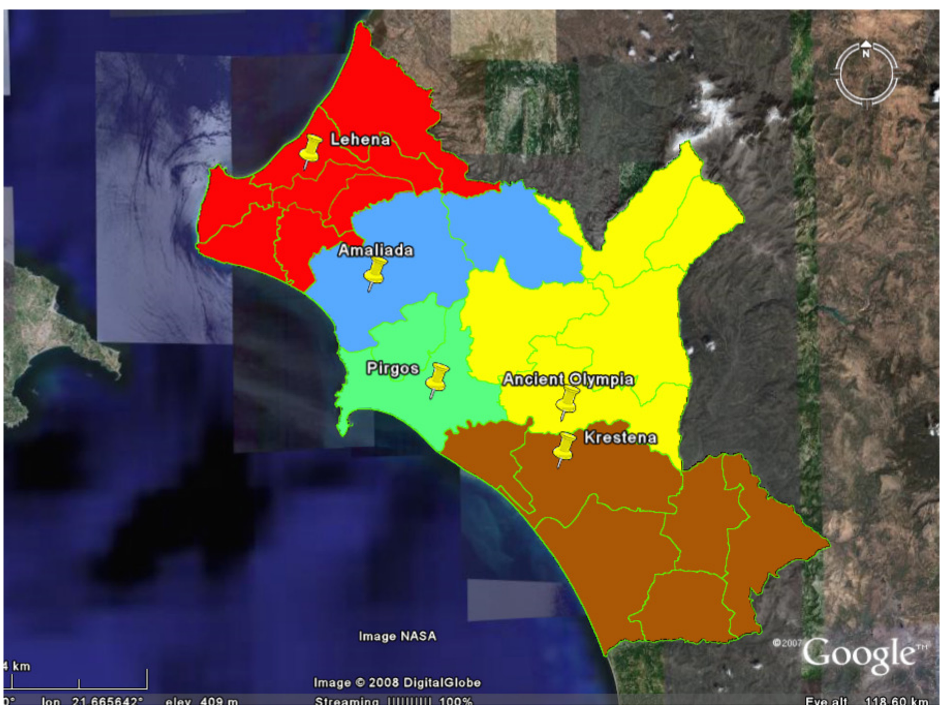

Figure 4.12: The fire stations in Elia.

Table 4.15: Fire fighting personnel and equipment capacity in each of the 5 fire stations of Elia.

	Personnel		Fire trucks	
Fire station	**Permanent**	**Seasonal**	**Forest**	**Urban**
Amaliada	35	25	8	
Pirgos	49	29	16	10
Olympia	20	44	6	4
Krestena	24	54	7	4
Lehena	49		4	
Total	**329**		**59**	

Officers in the fire station of Pirgos (the capital city of the state of Elia) suggested that the 5 fire stations in the state received hundreds of phone calls from civilians pleading for assistance during the 5-day crisis period. Given the infrastructure capacity of the fire department in the state, as well as the fact that 59% of the villages in Elia were affected by the fires (130 out of a total of 219 were burned), firefighters were in great scarcity during the 5 critical days (Georgiopoulos, 2008).

Apart from ground crews, aerial support is also of paramount importance in any wildfire suppression. During the summer of 2007 the fire fighting fleet of Greece (analyzed on table 4.16) was significantly reinforced by a total of 23 planes and 18 helicopters that were offered in the form of assistance by several European countries (Xanthopoulos, 2007b).

4 Erickson Air-Crane helicopters
7 MIL MI-26s helicopters
5 Kamov Ka-32s helicopters
13 Canadair CL-215 waterbombers
9 Canadair CL-415 amphibian waterbombers
19 PZL M-18 Bromader single engine airplanes
Total: 16 helicopters and 41 planes

Table 4.16: Aerial fire fighting capacity of Greece. Source: Xanthopoulos (2007b)

There are two bases hosting firefighting planes in the state of Elia. One in the military airport of the town of Andravida that hosts four Canadair CL-415 planes and one in the area of Epitalio that hosts two PZL M-18 planes (see appendix A for photographs illustrating the two types of planes). The latter are exclusively under the command of the Fire Department commander of Elia and can only be dispatched to other states in Greece with his approval (Giannakoulias, 2008). Figure 4.13 illustrates the geographic locations of the two airports.

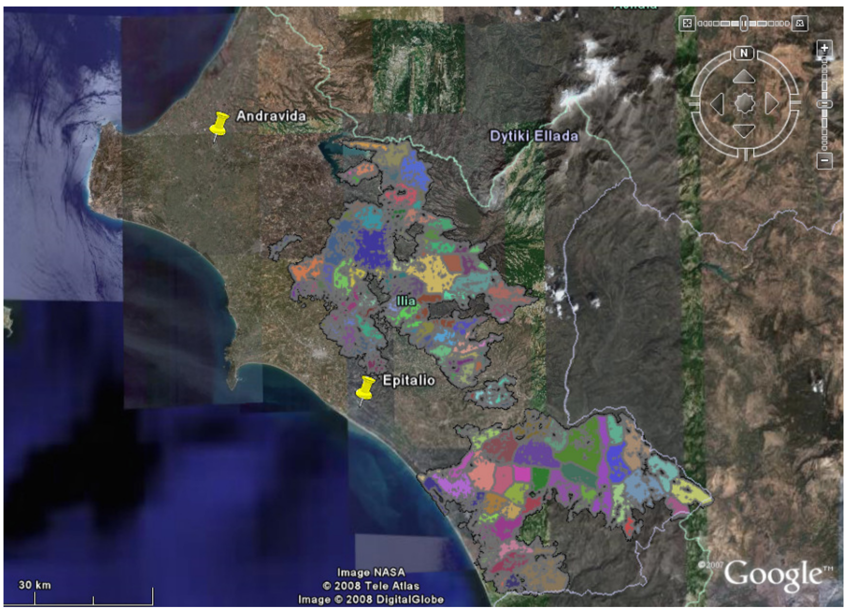

Figure 4.13: The airports of Andravida and Epitalio, host the fire fighting fleet of the state of Elia.

The presence of fire crews at the various villages as well as the operation of waterbombers are both important RHS variables in the attempt to explain the spread of the wildfires. Participants in the survey were asked to provide information on how many fire trucks came to their village, how long they stayed and finally to what extent they contributed to fire suppression. In addition, they were asked to recall whether or not fire fighting planes and/or helicopters operated within the boundaries of their village, and also to state the number of drops made.

It is important to clarify several issues at this point. First of all, as highlighted earlier in this chapter fire fighting personnel and equipment were in great scarcity during the 5-day crisis period, particularly if one considers the availability versus the need for fire suppression resources ratio. Approximately 330 firefighters with 60 vehicles had to respond to dozens of cases of threatened villages within a matter of days. In addition, the four Canadair CL-415 planes stationed in Andravida had to operate in other states that were threatened by wildfires during the same 5-day crisis period.

Ground forces in Elia were reinforced by fire fighting personnel from other states of Greece, as well as by foreign volunteers. Nevertheless, it was often the case that out-of-state fire fighters could not contribute significantly to suppression efforts. That could be explained by the fact that they lacked the knowledge of the local terrain, the landscape and the prevailing winds in the area. Information on all of these factors is often a matter of experience (that local people and fire crews working in the area for years posses) and certainly plays a critical role during wildfire suppression. Furthermore, the efforts of out-of-state fire crews were often curtailed by the fact that they were not informed as far as location of water refueling points was concerned. In addition, without being familiar with the local forest road network, they would often refrain from driving fire trucks into the woods in fear that they would end up in a dead end path without the option of turning the vehicle around (Field interviews, 2008).

After the tragic incident in Artemida, where 9 people lost their lives, the main preoccupation of the officials in charge of the crisis, was to protect human lives and people's houses, often neglecting woodlands and agricultural fields. It was often the case that a fire truck would arrive at a village with orders to remain in the main square and operate only to save burning houses. That would severely restrict the potential contribution of a fire crew since it was not allowed by its superiors to engage in suppression efforts in the woods and/or agricultural fields.

In their vast majority citizens of Elia acknowledged the contribution of fire crews and stated that fire fighters would often demonstrate heroic efforts to save people and property. However, blazes were so severe that both civilians and fire fighters were overwhelmed by the magnitude of the threat. As a senior citizen of the village of Smerna stated "*even if each and every one of us was a professional firefighter, we would still not have been able to extinguish the fire*". Another citizen of Makistos further emphasized the point: "*Even with 100 water bombers we would not have been able to suppress the blazes*" (Field interviews, 2008).

On a final note, it is important to state that participants in the survey could not be expected to be fully aware of the presence of fire crews or the operation of waterbombers within the boundaries of their village. For example, a crew or a fire plane could be operating in a remote location that villagers were not aware of and/or could not see. Hence people's responses with respect to presence of fire crews are used only as an approximation of the Fire Department's suppression efforts in their village. However, given that Fire Departments did not have specific records of the locations and points of operation of the fire crews during the 5-day crisis period (due to the overwhelmingly high volume of calls for help), this approximation is our best available source of data. It is certainly not the intention of the author to criticize or judge the work of the Fire Department. The only goal in the attempt to document the contribution of the

Department's suppression efforts is to examine to what extent it proved statistically significant to the damage that villages sustained from the wildfires.

After considering all of the above, we shall present a summary of the data regarding the presence of fire crews and operating waterbombers in the several villages. In the case of fire crews the following classification scheme was followed: 1) "None", meaning that no fire crews came to the village, 2) "low", indicating that 1 or 2 fire crews appeared and 3) "high", in cases where 3 or more fire crews operated in the village. In the formation of those categories we are also considering whether or not fire crews were reinforced by municipal vehicles carrying water, bulldozers and other heavy machinery, as well as army forces. Finally the effective contribution of the crew was also taken under consideration (Field interviews, 2008). Table 4.17 summarizes the data regarding presence of fire crews in the sampled villages.

Table 4.17: Presence of fire crews in the sampled villages.

Presence of firefighters	Number of villages	Percent
None	17	34.69
Low	18	36.73
High	14	28.57

As one can observe, fire crews were present in 65% of the villages sampled. Table 4.18 below, reveals that the highest rate of non-presence (54%, calculated on a per day basis) is recorded during the first day (i.e. 24th of August). As days went on non-presence rate decreases, while both presence categories (i.e. "low" and "high") increase.

Table 4.18: Presence of fire crews by day in the sampled villages

Presence of fire crews	Days of the fire				
	24	25	26	27	total
None	5	9	3	0	17
Low	3	8	6	1	18
High	1	6	6	1	14
Total	9	23	15	2	

We would expect that the percentage of area burned in a village would decrease as the presence of fire crews in the settlement increases. To test this hypothesis we performed a comparison of means t-test. Table 4.19 summarizes the results.

As expected, mean percent of area burned does decrease as presence of fire crews increases. The difference between no-presence and low-presence is only significant at the 5% level, while the difference between low-presence and high-presence is not statistically significant.

Table 4.19: Mean area burned (in percent), where villages are categorized based on presence of fire crews.

Variable	Observations	Mean of percent area burned	Std. Error	Std. Dev.	95% Conf. Interval	
Percent burned - no fire crew presence	17	**0.699698**	0.050542	0.208	0.592	0.806843
Percent burned - low fire crew presence	18	**0.560088**	0.063063	0.267	0.427	0.693139
Percent burned - high fire crew presence	14	**0.464848**	0.063853	0.238	0.326	0.602793

Table 4.20 summarizes the information gathered from the field with regards to operation of aerial fire fighting fleet. Category "None" indicates that no aerial support was provided, "Low" that 1-3 drops were made in within the boundaries of the village and "High" that 4 or more drops were made.

Table 4.20: Operation of water bombers in the sampled villages.

Operation of waterbombers	Frequency	Percent
None	31	63.27
Low	12	24.49
High	6	12.24

Our expectation is that a negative relationship would exist between the operation of waterbombers and the percentage of burned area in a village. Table 4.21 illustrates the results of the relevant t-test.

Table 4.21: Mean area burned (in percent), where villages are categorized based on operation of waterbombers.

Variable	Observations	Mean of percent area burned	Std. Error	Std. Dev.	95% Conf. Interval	
Percent burned - no planes	31	0.5993416	0.0455597	0.2536	0.5062	0.692
Percent burned - "Low" planes	12	0.5977942	0.0776191	0.2688	0.4269	0.768
Percent burned - "High" planes	6	0.4551983	0.0923137	0.2261	0.2178	0.692

There seems to be no difference in percent of area burned between the two first categories. However, as the number of drops increases (as is the case in the “high” category) the mean area burned decreases from 59% to 45%. This difference (i.e. between the “low” and “high” category) is significant at the 10% level.

4.3.1.4 Fire prevention

Fire prevention is of paramount importance in wildfire management. Traditionally the Greek Forest Service has been responsible for implementing a series of preventative measures such as creating fire break zones, reducing the amount of combustible fuel in the forests and keeping forest roads clear and accessible for fire trucks. However, when in 1998 fire suppression was removed from the jurisdiction of the Forest Service (which was left with the sole responsibility of fire prevention and post-fire management), the latter started becoming increasingly understaffed and poorly funded by the Greek administration. This, severely compromised the ability of the Forest Service to effectively carry out fire prevention operations (Giakoumis, 2008).

Participants in the survey were asked to recall whether or not (and to what extent) fire prevention efforts were being implemented in their village before the wildfire outbreak in late August. Their responses are classified into three categories:

"*None*" indicating that, to the best of their knowledge, nothing was done in terms of fire prevention.

"*Low*" indicating that the only fire preventive measure taken was the clearing of forest roads.

"*High*" indicating that apart from clearing forest roads, additional fire prevention measures were taken.

Table 4.22 summarizes the information on fire prevention in the sampled villages. There are 6 missing values for this variable, due to the fact that responses were judged as ambiguous or that participants could not recall whether fire prevention measures were implemented.

Table 4.22: Fire prevention measures in the sampled villages.

Fire prevention	Frequency	Percent
None	17	39.53
Low	22	51.16
High	4	9.3

Notice that in 39% of the villages sampled, no preventive measures were taken. In 51% of the villages the sole preventive measure was the maintenance of the forest roads. In most cases the maintenance is ordered by the Forest Service and implemented by workers of the county headquarters. It is important to note that, as indicated by the survey participants, forest roads were hardly (if at all) used by fire trucks. As mentioned previously in this chapter, the prevailing order to fire fighters was not to engage in suppression within the forest, but to help fight blazes that directly threatened houses or other infrastructure (Field interviews, 2008). As a result, most of the survey participants argued that maintenance of forest roads did not contribute significantly to fire mitigation efforts.

Only in 4 cases did we observe villages where additional preventive measures were implemented. These consisted either of night fire watch patrols organized on a voluntary basis by the locals starting from July and running through to September, or of voluntary clearance of the agricultural land in an effort to remove combustible fuel before the wildfires of August (Field interviews, 2008).

T-tests to examine whether fire-prevention actually had a significant contribution to reducing the percent of area burned in the villages were carried out. The results are summarized in table 4.23.

Table 4.23: Mean area burned (in percent), where villages are categorized based on fire prevention effort.

Variable	Observations	Mean of percent area burned	Std. Error	Std. Dev.	95% Conf. Interval	
Percent burned - No prevention	17	0.5346165	0.069145	0.2850922	0.3880356	0.681197
Percent burned - Low prevention	22	0.6528014	0.0489015	0.2293684	0.5511051	0.754498
Percent burned - High prevention	4	0.5702675	0.1165667	0.2331333	0.1993004	0.941235

The results in table 4.23 are counter-intuitive. It appears as if villages where no fire prevention was taking place suffered the least amount of damage. Villages in the "Low" prevention category had an average burned area of 65% (the highest of all three). "High" prevention category ranks second with a 57% average. The difference between the "Low" and "High" category is not statistically significant.

4.3.1.5 Fire history

The fire history of each village is the next RHS variable to be analyzed. That is, how many times had each village suffered a wildfire during the past 30 years. According to Miller and Urban (2000) past wildfires tend to reduce the risk of future wildfires. When an area is burned, flammable ground fuel is removed, thus making the region less prone to future wildfires. In addition, one could argue that if a village has suffered wildfires within the recent past, people would be more experienced in fire suppression and thus more likely to engage in fire abatement effort ultimately reducing the expected damage from the fire.

On the other hand wildfire history can play a different role particularly in the Mediterranean ecosystems, such as the one of the state of Elia. The halepius pine forests, predominant in the state, have a natural ability to protect themselves and ensure the continuity of the species in the event of a wildfire. The typical pine tree is approximately 30 feet tall and carries a total of 300 cones, 100 of each remain closed. Each cone contains roughly 70 viable seeds (Konstantinidis, 2003). The closed cones open up either during a wildfire or a within 48 hours and spread their seeds in a radius of 130 feet around the tree. As a result we have approximately 7,000 (100 cones * 70 seeds) potential new trees within that radius (see figure 4.14 for a visual approximation). This means that the new set of trees (that will grow the years following the wildfire) will be much thicker than the older one, thus increasing the amount of combustible fuel and make the area more prone to future wildfires (Konstantinidis, 2003). From that perspective, one could argue that past wildfires increase the danger for future wildfires, by increasing the density of the forest.

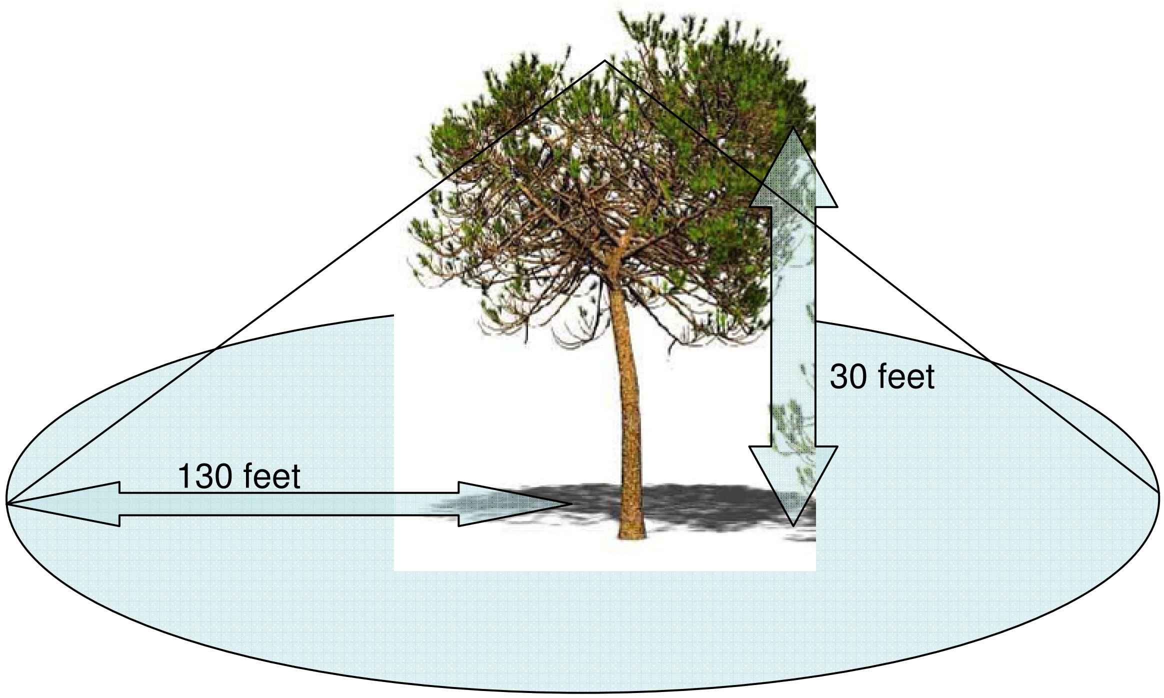

Figure 4.14: Graphical illustration of germinating area around a pine tree. Source: Konstandinidis (2003)

The ambiguous relationship of the "fire history" variable to wildfire risk (and thus in our case percent of area burned) is indicative of the complexity of the wildfire phenomenon. It is often the case that specific factors affect wildfire risk in counteracting ways. Prestemon et al. (2002) provide the example of housing density arguing that it can have both a positive and a negative effect on wildfire risk. The greater the number of houses in an area the higher the probability of faster detection of a wildfire. Furthermore, more houses could mean more people available to engage in fire suppression. All of the above would decrease wildfire risk. On the hand greater housing density might increase the probability of accidental or deliberate fire ignition.

The data on wildfire history was clustered based on the historical occurrence of forest fires in each village. Four different categories were created:

a) 0 if there has never been a wildfire in or near the village

b) 1 if the village had sustained damages from a wildfire within the past 10 years

c) 2 if the village had sustained damages from a wildfire within the past 10 to 20 years

d) 3 if the village had sustained damages from a wildfire within the past 20 to 30 years

Table 4.24 summarizes the data on wildfire history for the sampled villages. The interesting point is that approximately 64% of the sampled villages had not faced a wildfire within the last 20 years. As a result one could assume that the fuel built up in those areas would be considerably high. A series of t-tests was conducted in order to investigate the differences between mean percent of area burned for the villages included in each category of the wildfire history variable. The results are summarized on table 4.25.

Table 4.24: Wildfire history categories and respective frequency of villages.

Wildfire history	# of villages	Percent	Cumulative percentage
0	11	25	25
1	7	15.91	40.91
2	10	22.73	63.64
3	16	36.36	100

Table 4.25: Mean area burned (in percent), where villages are categorized based on wildfire history.

Wildfire history	Observations	Mean area burned	Std. Error	Std. Dev.	95% Conf. Interval	
0	11	0.5787027	0.0734977	0.2437645	0.4149395	0.742466
1	7	0.5462486	0.1065572	0.2819239	0.2855125	0.806985
2	10	0.687103	0.0723833	0.2288962	0.5233605	0.850846
3	16	0.5498663	0.064844	0.259376	0.4116545	0.688078

There appears to be no significant difference between the various categories of wildfire history. Categories 1 and 3 have a 54% mean of area burned while category 0 a

57.8%. The only significant deviation seems to be category 2 with a 68.7% of area burned. As a result no clear statistical pattern can be extracted from the wildfire history variable, other than the presumption that villages that had suffered a wildfire during the last 10-20 years are in greater risk compared to other villages.

4.3.1.6 Electrical blackouts and water availability

Water, although just one of the many fire suppression tools, is of paramount importance. It's availability during the days of the wildfires was an issue incorporated in the questionnaire. Survey participants were asked whether water was available during the time that the fire was in the village.

An issue closely related to water availability was the occurrence of electrical blackouts. Most of the villages in the state of Elia have a water provision infrastructure that is built around the use of water pumps. Water is being pumped to a main municipal tank, situated at a high altitude, and is then distributed to the houses for domestic use. In addition, given that most of these communities are agricultural, many farmers use generators to pump water from underground wells. It was often the case, during the 5-day wildfire period of August, that when the blazes would approach a village wooden electric poles would burn. Hence, electrical blackouts were frequent (Field interviews, 2008). Table 4.26 provides an overview of the number of villages that faced electrical blackouts before, but mostly during the time that the fire was within the boundaries of the village.

Table 4.26: Electrical blackouts during the time that the fire was within the boundaries of a village.

Electrical black outs	Number of villages	Percent
None	9	19.15
Intermintent	3	6.38
Constant	35	74.47

In the majority of cases where electricity was cut, water was soon after no longer available. The time period between the electrical black out and the end of water provision depended on two things:

1) whether or not the municipal water tank was full, or not, at the time of the black out.
2) whether or not villagers were prepared for the fire. In some cases, especially during the second and third day of the fires, people would start gathering water before the fire reached their village (in tanks, buckets or even kitchen pots) since they anticipated that shortages were likely to occur. That increased both water availability during the fire as well as the period between the black out and the depletion of reserves in the municipal water tank. In cases were villagers did not gather water in advance (either due to lack of time to respond or due to negligence), the depletion period was shorter.

Furthermore, in some villages electrical blackouts did not affect water availability since water provision infrastructure in those settlements does not depend on the availability of electricity. Rather those villages are watered through natural springs.

Data on water availability are summarized on table 4.27. The three categories, “low”, “medium” and “full”, are explained below:

1) Low availability: Water was either immediately cut off upon the electrical black out, or soon after (i.e. within a matter of minutes). Villagers had not gathered water in advance.
2) Medium availability: Water was cut off soon after the electrical black out occurred. Villagers had gathered water in advance.

3) Full availability: Village's water provision infrastructure is independent of availability of electricity, or no electrical black out occurred.

Table 4.27: Water availability in sampled villages.

Water availability	Number of villages	Percent
Low	19	39.58
Medium	14	29.17
Full	15	31.25

Presumably water availability would contribute significantly to fire suppression efforts. One could argue that villages with higher water availability would have sustained less damage. To test this hypothesis we run three consecutive t-tests in order to compare the percentages of area burned for the villages included in the three categories of water availability. The results are presented on table 4.28.

Table 4.28: Mean area burned (in percent), where villages are categorized based on water availability at the time of the fire.

Variable	Observations	Mean percent of area burned	Std. Error	Std. Dev.	95% Conf. Interval	
Percent burned - Low water availability	19	**0.560391**	0.05942	0.259004	0.435555	0.685227
Percent burned - Medium water availability	14	**0.699803**	0.052545	0.196606	0.5862859	0.81332
Percent burned - Full water availability	15	**0.51081**	0.071016	0.275045	0.3584954	0.663125

The results in this case are counterintuitive. We would expect that percent of area burned would decrease as water availability increases. However, this is not the case, at least for the transition between low and medium availability. We observe that mean percent of area burned increases from 56% to 70%. Furthermore the decrease observed between the low and full availability percentages is not statistically significant.

4.3.2 Meteorological data

Perhaps the most important piece of secondary data is the information on the meteorological conditions before, but mainly during the days of the fires. Overall, the climatic environment in the state of Elia is characterized as warm with a very dry and hot summer period (Agricultural University of Athens, 2007). There are 6 meteorological stations in the state of Elia. We were able to gather data regarding daily temperature, humidity, wind speed and direction from 3 of those stations (their geographic locations are illustrated on figure 4.15). The data from stations 1 (Pirgos station) and 3 (Andravida station) are on a 3 hour interval (for the period of August 22nd-September 9th 2007), while data from station 2 (Amaliada station) are on a 10 minute interval (for the period of August 1st to August 31st 2007).

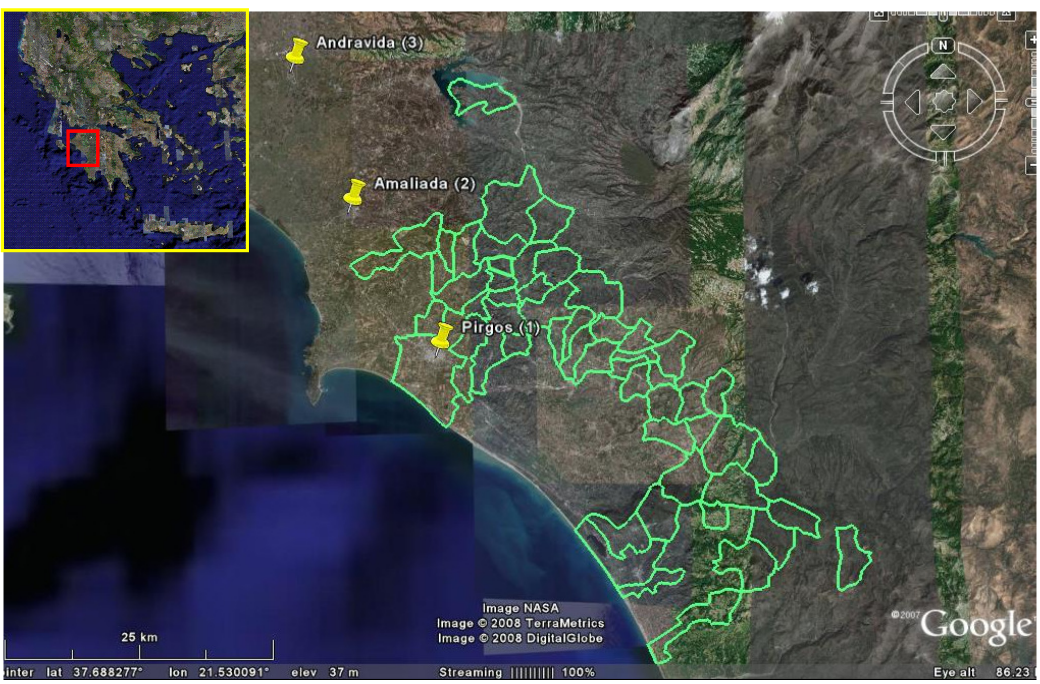

Figure 4.15: Location of the 3 meteorological stations in the state of Elia where data was obtained from. Stations are illustrated by yellow pins.

Data for the month of August on humidity, wind speed, as well as maximum and minimum temperature from the meteorological station of Andravida are presented on figures 4.16, 4.17 and 4.18 respectively.

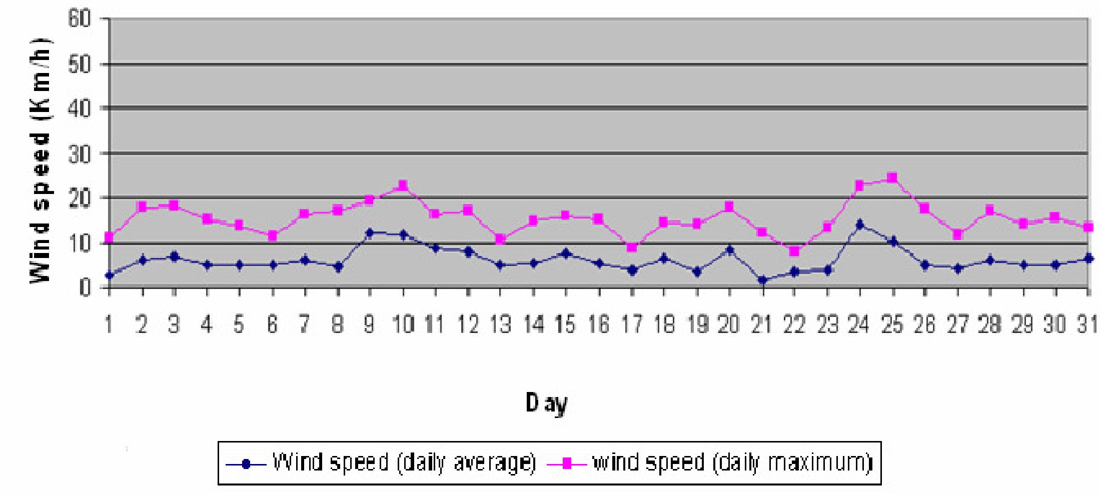

Figure 4.16: Wind speed in km/hour on a daily basis for August 2007, from the meteorological station of Andravida. Source: Statheropoulos et al. (2007).

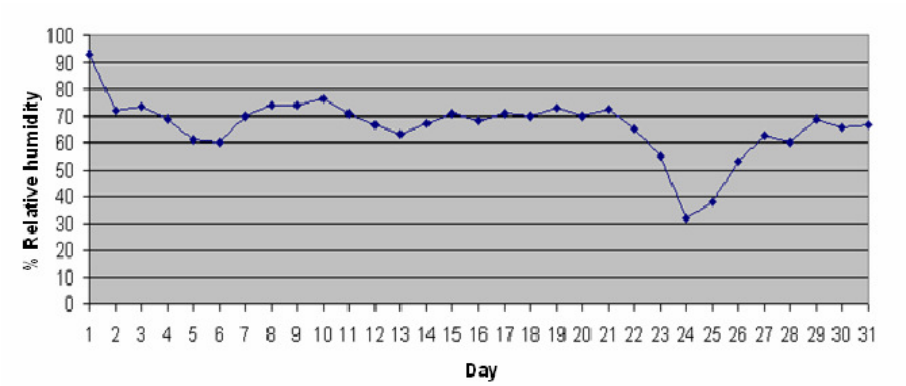

Figure 4.17: Relative humidity on a daily basis for August 2007, from the meteorological station of Andravida. Source: Statheropoulos et al. (2007).

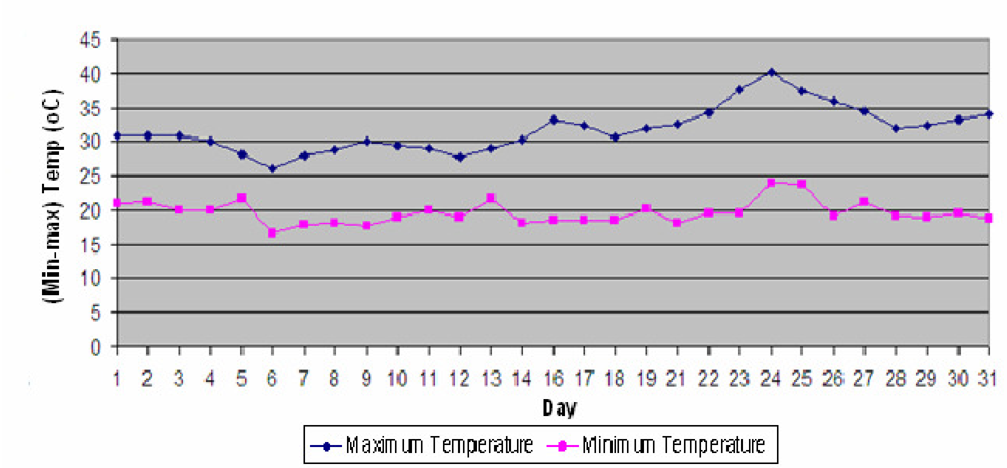

Figure 4.18: Min and Max temperature on a daily basis for August 2007, from the meteorological station of Andravida. Source: Statheropoulos et al. (2007).

An observation of the three figures above, illustrates the fact that on the 24th of August wind speed as well as temperature reached a monthly maximum, while relative humidity was at it lowest point. Thus, meteorological conditions had created a "lucrative" environment that would enable any wildfires starting on that day to spread rapidly.

As far as wind direction is concerned, a very important issue has to be addressed at this point; the issue of the diversion of the "meltemi" wind. Every year during the month of August there is a prevailing north-east wind that blows through the Aegean Sea (the sea between Greece and Turkey). It is a gale force wind that often causes severe problems to maritime transportation. This wind is known as the "meltemi". The pattern and traditional direction of the meltemi are illustrated on the left frame of figure 4.19. During the summer of 2007 the direction of the meltemi changed. By what was characterized as the "diversion of the meltemi" the August wind followed a different pattern illustrated on the right frame of figure 4.19. This diversion significantly attributed to the overwhelming spread of the wildfires (Theodorou, 2008).

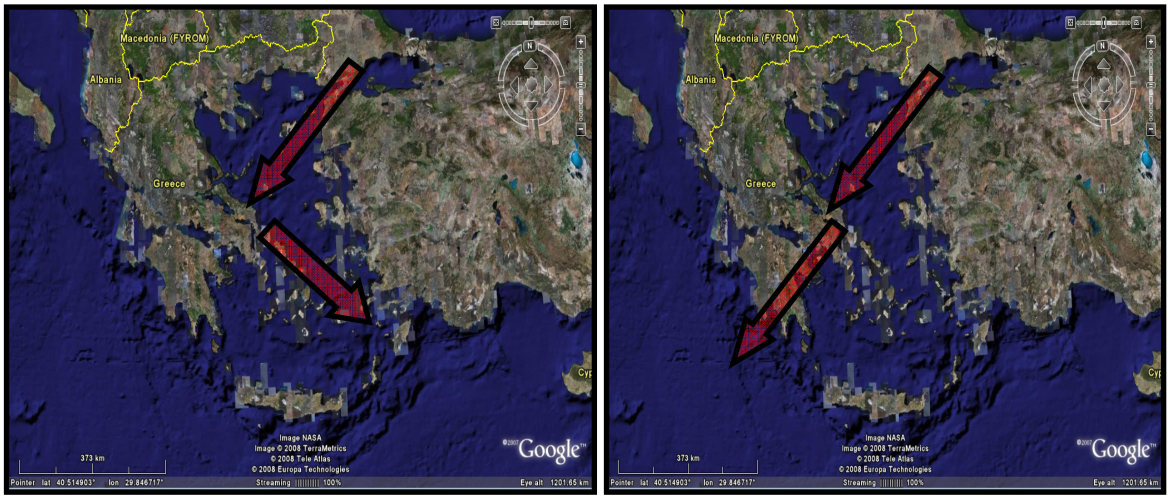

Figure 4.19: The diversion of the "meltemi" wind. The left frame represents the traditional route of the wind. The right frame illustrates the diversion of the wind that occurred during August 2007. Source: Theodorou (2008).

Keeping in mind that the prevailing wind direction was south west and combining that fact with the locations of the initial blazes illustrated on figure 4.20 one could arrive to useful conclusions regarding the spread of the fires. That is, the 4 blazes that were not contained (i.e. Klindias, Palaioxori, Sekoulas and Valmi), spread towards the south west, aided by the prevailing wind direction of the meltemi.

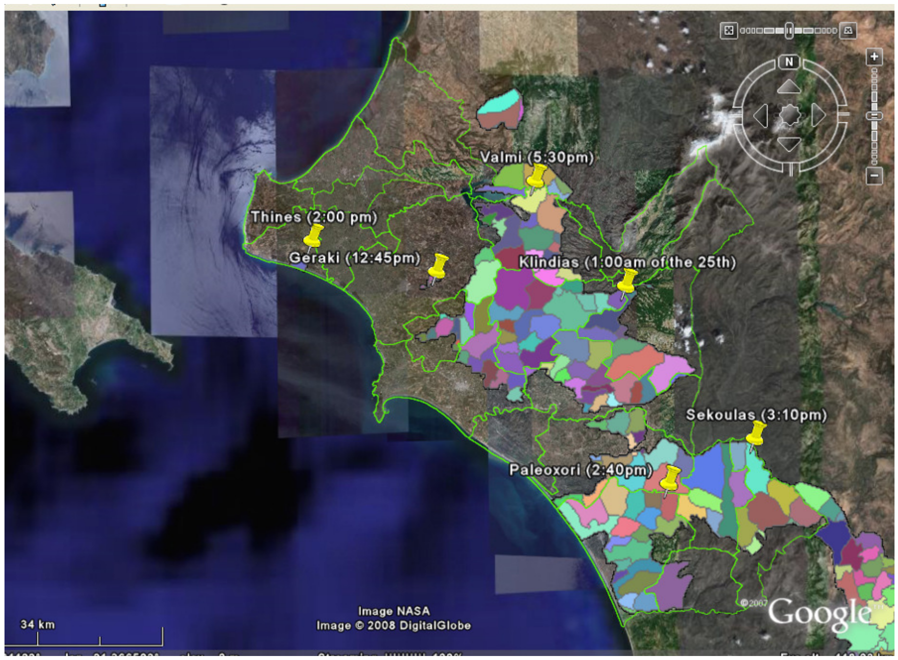

Figure 4.20: Locations of the 6 initial blazes on August 24th (marked by yellow pins).

As stated previously, meteorological data were gathered from 3 weather stations. Data from the station of Pirgos had missing values and were thus dropped. In the remaining two stations (those of Amaliada and Andravida) data were measured on different time intervals. In this section we are presenting data from both stations. Tables 4.29 and 4.30 provide a comparison between wind speed as measured in the two weather stations. Values represent wind speed at the time the fire arrived at each sampled village.

Table 4.29: Wind speed measured in the beaufort scale (0-12) at the weather station of Andravida.

Wind speed in beaufort (Andravida)	Number of villages	Percent	Cumulative percentage
0	15	30.61	30.61
1	5	10.2	40.82
2	15	30.61	71.43
3	10	20.41	91.84
4	4	8.16	100

Table 4.30: Wind speed measured in kilometers per hour at the weather station of Amaliada.

	Observations	Mean	Median	Std. Dev.	Min	Max
Wind speed in km/h	49	6.505102	8	3.714571	0.15	11.3

The way the above tables were created is the following. In every village sampled the survey participants were asked to recall at what time the fire approached their village. Consequently the recorded times for each settlement were matched with the relevant wind speed at the weather stations of Andravida and Amaliada. For the station of Andravida wind speed was measured in the discrete beaufort scale. Wind speed values from that station ranged from a minimum of 0 to a maximum of 4. What is more, data were recorded on a 3 hour interval (i.e. 12:00 am, 03:00 am, 06:00 am, etc.). If the fire arrived at the village at 2:30 am we would assign the wind speed that was recorded at the closest time (i.e. 03:00 am).

On the other hand in the station of Amaliada wind speed was measured on a 10-minute interval. In this case we would average the wind speed for a period of 1.5 hour before and 1.5 hour after the fire arrived at the village and assign the resulting value to the settlement. Note that we are making the assumption that the wind speed measured at Amaliada and Andravida was the same (or at least not significantly different) as the wind speed in any of the sampled villages. This, of course, is a rather bold assumption. Ideally, we would like to have meteorological information from each sampled village at the time of the fire. However, that kind of precision is not possible to achieve[10].

A similar methodology was followed for the attribution of humidity values to sampled villages, presented on table 4.31.

Table 4.31: Humidity (in percent) at the time of the fire for the sampled villages.

Variable	Observations	Mean	Median	Std. Error	Min	Max
Humidity (Andravida)	49	38.79592	39	14.76479	15	81
Humidity (Amaliada)	49	25.51837	21.5	10.52324	15.8	54.3

[10] Unlike standard practice in the US, Greek fire crews do not have any of their members recording meteorological information during the time of the wildfire. Thus, precise weather data are not available.

In order to examine the significance of wind speed and humidity to the spread of the fires, we conducted a series of t-tests for the 2 different stations. We separated villages in two groups based on median wind speed and humidity. We then averaged the percent of area burned for low wind speed/humidity villages vs high wind speed/humidity villages and determined whether the differences in area burned between the various groups were statistically significant or not. Results are presented on tables 4.32 through 4.35.

Table 4.32: Mean of area burned (in percent), where villages are categorized based on low or high wind speed as measured in the station of Andravida. Difference is significant at the 10%.

Adravida station	Observations	Mean	Std. Error	Std. Dev.	95% Conf. Interval	
Low wind speed	20	0.52278	0.051	0.228	0.415	0.629756
High wind speed	29	0.6216797	0.049	0.266	0.520	0.722872

Table 4.33: Mean of area burned (in percent), where villages are categorized based on low or high wind speed as measured in the station of Amaliada. Difference is counter intuitive and not statistically significant.

Amaliada station	Observations	Mean	Std. Error	Std. Dev.	95% Conf. Interval	
Low wind speed	25	0.59485	0.049	0.2467	0.4929	0.696
High wind speed	24	0.5672108	0.0541	0.2653	0.4551	0.679

Table 4.34: Mean of area burned (in percent), where villages are categorized based on low or high humidity as measured in the station of Andravida. Difference is significant at the 10% level.

Andravida station	Observations	Mean	Std. Error	Std. Dev.	95% Conf. Interval	
Low humidity	24	0.6332988	0.0555575	0.272	0.5183	0.748
High humidity	25	0.5314056	0.0458097	0.229	0.4368	0.625

Table 4.35: Mean of area burned (in percent), where villages are categorized based on low or high humidity as measured in the station of Amaliada. Difference is significant at the 10% level.

Amaliada station	Observations	Mean	Std. Error	Std. Dev.	95% Conf. Interval	
Low humidity	24	0.6372775	0.0505154	0.2474	0.5327	0.741
High humidity	25	0.527586	0.0505658	0.2528	0.4232	0.631

As far as wind speed is concerned, results from the station of Andravida are statistically significant (at the 10% level) and of the expected sign. That is, stronger winds exacerbated the spread of the wildfires and led to a greater percent of area burned. On the other hand, the data from Amaliada provide results that are counter intuitive (mean area burned in "low" wind speed villages = 59% vs mean area burned in "high" wind speed villages = 56%) and not statistically significant.

Greater consistency appears amongst humidity data from the two different stations. Results are almost identical, with villages where humidity was below the median having a mean area burned of 63% with the relevant figure for "high" humidity villages being 53% (difference is significant at the 10% level). The difference is of the direction we would anticipate, since greater humidity increases the amount of time that combustible fuel needs to ignite. Therefore, areas where humidity levels were high when they were reached by the fires, suffered relatively less damage.

4.3.3 Topographic data

The state of Elia covers an area of 2,681 km^2 (the US state of Rhode Island is slightly larger with an area of 3,144 km^2). The landscape is dominated by lowlands and hills, with mountains comprising only a small percentage of the total area. Tables 4.36 and 4.37 below, provide brief summary of elevation and slope data for the state.

Table 4.36: Distribution of elevation zones for the state of Elia. Source: Agricultural University of Athens (2007)

Elevation zones in meters	Area included in the zone (Km^2)	Percentage of total area of the state in percent (%)
< 100	1029	39
100 - 300	788	30
300 - 700	538	21
> 700	262	10

Table 4.37: Terrain slope analysis of the state of Elia. Source: Agricultural University of Athens (2007)

Classification	Slope (%)	Percentage of area %
Flat	<10	30
Relatively flat	10-20	30
Medium	20-30	20
Steep/very steep	>30	20

Table 4.38 below, provides a summary of the main descriptive statistics for the altitude and slope of the sampled villages. The way the values for elevation and slope were calculated was the following. The digital area contained within the administrative boundaries of each village includes a specific number of pixels. Each pixel has an area of 10,000 square feet (as analyzed in section 4.2). With the use of GIS software we were able to identify the individual altitude (and slope) of each pixel and then calculate the average of altitude (and slope) over all the pixels comprising a village.

Table 4.38: Summary statistics for the topographical variables in the model

Variable name	Observations	Mean	Median	Std. Dev.	Min	Max
Elevation (in meters)	49	201.55	142.77	159.44	54.25	827.32
Slope (in degrees)	49	10.53	10.54	3.74	3.32	19.23

In an attempt to examine which of these variables had a significant effect to the spread of the wildfires we conducted a series of t-tests between each of the variables and the percent of area burned of each village. Tables 4.39 and 4.40 present the results of the tests.

Table 4.39: Mean area burned (in percent), where villages are classified based on elevation.

Variable	Observations	Mean area burned (in percent)	St. Error	Std. Dev.	95% Conf. Interval	
Percent burned-low altitude	24	0.484851	0.042686	0.209	0.3965	0.573154
Percent burned-high altitude	25	0.673915	0.052386	0.261	0.5657	0.782035

In order to create table 4.39 we classified villages in two different categories, based on their median elevation. Villages located at an elevation lower than 142.77

meters (the sample median) were classified as "low elevation", while settlements placed at an altitude higher than the median were classified as "high elevation". We then took the average of the percent of area burned for each category. The mean percent burned for the "low altitude category" is 48.5%, while the respective number for the "high altitude" category is 67.4%. This suggests that villages located in low altitudes sustained significantly less damage than the ones positioned in higher altitudes. The difference is significant at the 1% level.

Table 4.40: Mean area burned (in percent), where villages are classified based on slope.

Variable	Observations	Mean area burned (in percent)	St. Error	Std. Dev.	95% Conf. Interval	
Percent burned-low slope	24	0.463863	0.046197	0.226	0.3682	0.559
Percent burned-high slope	25	0.694064	0.045883	0.229	0.5993	0.788

A similar classification was conducted, this time based on slope. Villages with a slope less than the median (i.e. 10.54%) were classified as "low slope", while the rest as "high slope". The mean percent of area burned was calculated for each of the two categories. As observed in table 4.38 villages in steeper slopes were affected on a larger scale by the wildfires, when compared to villages located at slighter slopes. The relevant percentages of areas burned for settlements in steep vs. slight slopes are 69.4% and 46.38% respectively. The difference is significant at the 1% level.

Judging from Tables 4.39 and 4.40 one could argue that topography played a significant role in the damage that villages sustained form the wildfires. Settlements located at high altitudes as well as steeper slopes saw 67% and 68% respectively of their areas being burned. One could make the case that topography could have played a role in people's decision to engage in fire suppression, as well as in the presence of firefighters in the area. This could be explained by the fact that geographical remote villages were harder for fire trucks to reach, and also did not facilitate people's participation in fire suppression, hence were burned more severely.

On the other hand, the relationship between altitude and percent of area burned could be running the opposite way from that suggested in table 4.39. More specifically one would expect increased relative air humidity levels at high altitudes. That would in turn increase ground fuel moisture, thus decreasing the rate of spread of a fire. In other words, altitude could be negatively related to percent of area burned.

4.3.4 Demographic variables

Elia has a population of 183,521 people, which makes it the 11th most populated state (out of a total of 51 states) in Greece (General Secretariat of National Statistical Service of Greece, 2001). Citizens in their majority live in rural areas and make their living primarily from agriculture and animal husbandry.

Table 4.41 presents the three demographic variables of choice; population, road network and total area of each village[11].

Table 4.41: Demographic data include population, total village area and length of road network.

Variable name	Observations	Mean	Median	Std. Dev.	Min	Max
Total area (in thousand sq. meters)	49	9,856	9,025	5,175	3,039	26,300
Population	48	615.46	445.50	916.57	68.00	6,492.00
Road network (in meters)	49	41,166	38,388	20,322	12,973	102,352

[11] We have one missing observation in the population variable due to the fact that the village of Lambeti, adjacent to the state capital of Pirgos, was conceived administratively as being part of the capital.

As illustrated on Table 4.41 every village has an average of 615 inhabitants (slightly lower than the state average of 838 people), includes a total area of almost 10 km^2 and has a road network that stretches across 42 km.

To determine to what extent population plays a role in the amount of damage that a village sustained from the wildfires we decided to create a population density variable (i.e. number of people per km^2). Table 4.42 provides a summary of the main descriptive statistics for the new variable.

Table 4.42: Summary of statistics for population density

Variable	Observations	Mean	Median	Std. Dev.	Min	Max
Population density (number of people per km^2)	48	60.34	55.39	46.19	12.11	294.21

By conducting a t-test we can observe that villages with a population density lower than the median (i.e. 55.39) sustained on average more damage than those with a higher population density. Results are presented on table 4.43. Note that the difference is significant at the 5% level.

Table 4.43: Mean area burned (in percent) where villages are categorized based on population density.

Variable	Observations	Mean	Std. Error	Std. Dev.	95% Conf. Interval	
Percent burned - Low population density	24	0.646317	0.056783	0.27818	0.528	0.763
Percent burned - High population density	24	.5158271	.0447571	.2192641	.4232	.6084

Intuitively the above result could be justified by the fact that more densely populated villages suffered less damage given that there were more people to protect the settlement.

Another demographic variable of interest is the length of the road network in every village. As illustrated on Table 4.41 every village has an average road network of 42 km. Total road network consists of several different types of road surfaces. These are:

Road2: All weather hard surface road, two lanes wide

Road3: All weather loose surface road, two lanes wide

Road4: Cart track

Road5: Normal gauge railroad, single track

Road28: All weather hard surface road, one lane wide

Road30: Fair or dry weather loose surface road

Table 4.44 below provides the descriptive statistics of the 6 different categories of roads that comprise the aggregate variable "Road network".

Table 4.44: An analytical description of the different categories and types of roads.

Variable	Observations	Mean	Median	Std. Dev.	Min	Max
Road network	49	41,166.89	38,388.54	20,322.59	12,973	102,352
road2	49	4,092.69	3,463.86	4,535.59	0	28,104
road3	49	1,108.01	0	1,934.88	0	10,048
road4	49	25,944.05	25,104.54	13,113.59	1,515	62,265
road5	49	419.38	0	1,299.18	0	8,163
road28	49	412.05	0	1,764.53	0	11,546
road30	49	9,190.71	5,828.10	11,790.31	19.05	58,146

The greater part of the road network falls under the "road4" (cart track) and "road30" (fair or dry weather loose surface road) categories. As a result one can understand that the transportation infrastructure in the sampled villages is of rather poor quality.

In an attempt to relate the road network variable to the percent of area burned it could be suggested that the better/longer the road network within a village the easier the access of the fire trucks, as well as of the civilians to the blazes and thus the more effective the fire suppression effort. In addition, a wide enough-two lane road could be used as a fire break zone that would facilitate the work of firefighters, since it would add to the fragmentation of combustible fuel. We would expect therefore that villages with a higher road network density would on average have a lower percentage of area burned, than settlements with lower road network density. We are assuming here that, since the summers in Elia are relatively dry, all 6 road categories would be in good condition (i.e. lack of precipitation would create favourable conditions for driving even on dirt roads). In order to facilitate our statistical comparison we created a variable labeled "Road density" denoting length of road network per square kilometer for every village. Table 4.45 presents a summary of the main descriptive statistics for the road density variable. Note that the aggregate variable "Road density" (which is comprised of the sum of the six different road categories presented on the previous page) is the one used for the calculations in both tables 4.45 and 4.46.

Table 4.45: Road density descriptive statistics summary.

Variable	Observations	Mean	Median	Std. Dev.	Min	Max
Road density (km of roads per km^2 of area)	49	4,345.81	4,274.86	856.195	2,434.01	6,332

In Table 4.46 we have divided villages in two categories: 1) low road density, indicating that within the administrative boundaries of the settlement there exist less than 4,274.86 km (i.e. the median road density) of roads per square kilometer and 2) high road density, indicating that within the administrative boundaries of the settlement there exist more than 4,274.86 km of roads per square kilometer. To test our hypothesis we will perform a t-test. The results are summarized on table 4.46.

Table 4.46: Mean area burned (in percent), where villages are categorized based on road density.

Variable	Observations	Mean area burned (in percent)	Std. Error	Std. Dev.	95% Conf. Interval	
Percent burned - Low road density	24	0.598473	0.052468	0.25704	0.4899343	0.707012
Percent burned - High road density	25	0.564838	0.050935	0.254674	0.4597141	0.669963

It appears that villages with lower road density sustained greater damage from the fire (area burned=59.8%) as opposed to high road density villages (area burned=56.4%). However, the difference is not statistically significant and counter intuitive.

4.3.5 Vegetation coverage

Agriculture is the primary economic activity in the state of Elia. The state is known as the "garden of Greece" because of it's fertile soil and the various crops that are grown there. Two of the most important crops are olives and grapes. The predominant type of landholding in the state includes relatively small plots of either olive groves or vineyards (sometimes less than a hectare) that are scattered sometimes even within woodlands (Field interviews, 2008). Figure 4.21 provides and illustration of the above point.

People in the region are heavily dependent on these two types of crops for their livelihoods. In several cases farmers would try to protect their fields from the fire, knowing that if those fields were burned their economic future would be jeopardized, since they would be loosing their primary income generating resource. In addition, if an olive grove is burned completely and is consequently replanted it takes at least 10-15 years until the farmer can harvest a commercially significant crop volume again (Field interviews, 2008). As a result the motivation to protect olive groves and vineyards was very high.

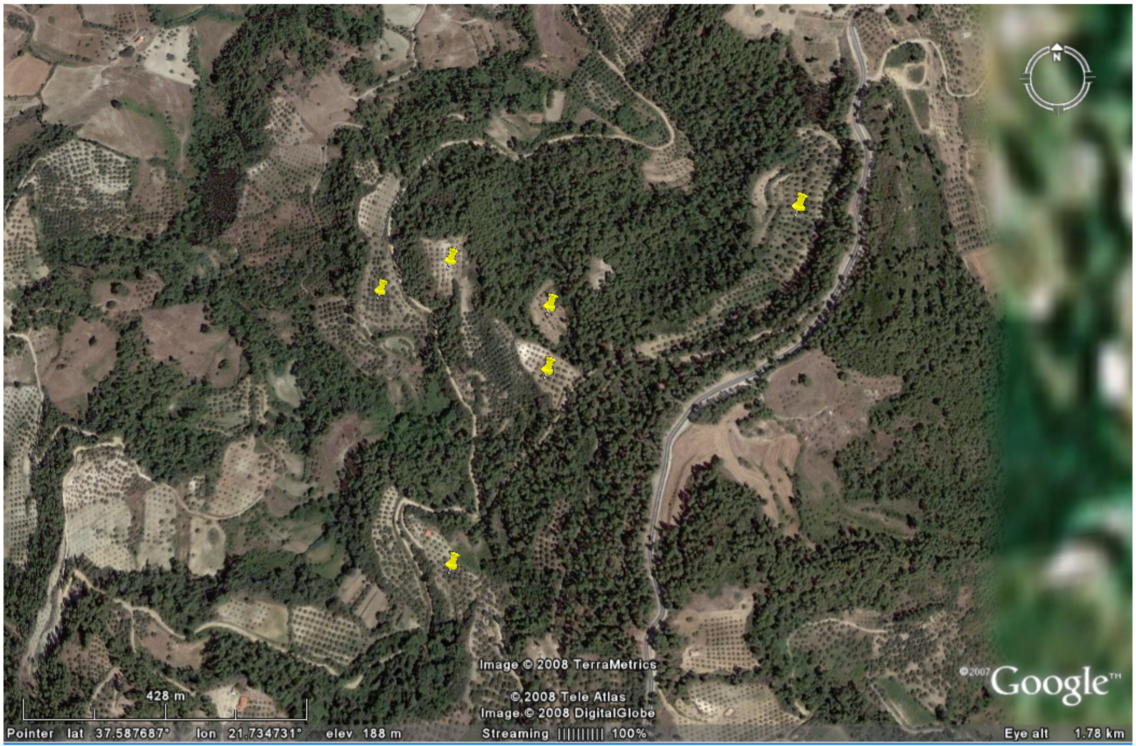

Figure 4.21: Forest area east of the village of Ploutoxori. The yellow marks represent olive groves scattered within the woodlands. This is a very common pattern in the state of Elia.

Furthermore, the relationship between olive groves and the spread of the fire has yet another aspect. The predominant agronomic pattern in the state is for farmers to clear the ground vegetation (i.e. weeds, etc.) in their olive groves during the period between April to July. The reason for doing this is two-fold. Primarily it contributes to the health of the field since weeds take up soil nutrients, vital for the growth of the olive tree. Secondly, it provides some means of wildfire prevention. Given that weeds are highly flammable fuel for wildfires, once thoroughly removed they reduce the fire risk a specific agricultural field faces. The same weed removal practice is also followed in the case of vineyards (Field interviews, 2008).

There are two main ways that farmers use to clear ground vegetation from an olive grove. One method is by plowing the land and the other by using a weed trimmer machine commonly referred to by the locals as “the destructor” (Field interviews, 2008). The two machines are illustrated in figure 4.22.

Figure 4.22: Machines used for clearing ground vegetation in Elia. The plowing machine is illustrated on the left frame, while the so-called “destructor” on the right.

There is an important distinction between the two methods. Using the destructor is a cheaper option, since the work requires less effort on the part of the tractor user and less fuel for the tractor itself. The trimmed vegetation stays on the field acting as a natural fertilizer for the olive trees. However, as it dries out during the subsequent months of the summer, it becomes a highly combustible fuel and increases wildfire risk. One the other hand use of the plow is more strenuous and costly. Unlike the destructor however, once a field has been plowed there is hardly any vegetation left on the land, thus minimizing wildfire risk (Field interviews, 2008).

It was often the case that adjacent olive groves treated with the two methods suffered highly differentiated levels of damage by the wildfires. The norm was for plowed fields to have sustained little to no damage, while olive groves treated with the destructor to have been completely burned (Field interviews, 2008). Figure 4.23 provides an illustration of the above point.

Figure 4.23: Differences in level of damage due to the application of the two different land management treating methods. The field on the left was plowed, while the adjacent olive grove was managed with the use of the destructor.

Local farmers were aware of the strengths and weaknesses of each method with respect to wildfire risk even before the 2007 season. However, very few could imagine that such a devastating destruction would take place. The vast majority of the survey participants argued that people in their community have decided not to use the destructor again, after seeing the consequences that this method had on a number of olive groves.

In an effort to explore the quantitative relationship between the presence of olive groves/vineyards and the amount of damage caused to a village by the wildfires, we gathered data regarding the olive grove/vineyard coverage in each village. The data were extracted from the "registry of olive groves" of the Department of Agricultural Development of the State of Elia.

Each farmer has the obligation to report to the state authorities the number of olive trees as well as the olive grove acreage in his possession on an annual basis in order to receive the federal subsidy. As a result, a "registry of olive groves" is developed by the Department of Agricultural Development. One of the problems with this kind of registry is that poor monitoring often results in farmers over-stating the acreage in their procession in an effort to receive more subsidies.

An additional motive to declare this information to the state is provided by the fact that in the event of extreme weather conditions (such as a drought or a hale storm) farmers are going to be compensated by the state for the damages that they will have sustained based on the "registry of olive groves". Farmers that have not registered an olive grove will not receive compensation for damages sustained on that field.

Table 4.47 provides an overview of the descriptive statistics for the acreage of olive groves and vineyards in the villages sampled.

Table 4.47: Mean percentage of olive groves and vineyard acreage in the sampled villages.

Percent of acreage	Observations	Mean	Median	Std. Dev.	Min	Max
Olive groves	47	0.3213579	0.303	0.1430397	0.0347448	0.740928
Vineyards	47	0.0853273	0.051	0.0973998	0.0016577	0.429732

The mean acreage of olive groves is relatively large with the average village having 32% of it's area covered by olive groves. Vineyards take up much less space with a mean acreage of just 5%.

The hypothesis is that the greater the acreage of olive groves/vineyards within the boundaries of a village the lower the burned area. As analyzed above this would be justified by the fact that farmers would be more likely to engage in fire suppression in order to protect those crops. Additionally those two types of fields would help reduce the spread of the fire due to the reduced volume of combustible ground fuel found on them. Table 4.48 presents the results of the hypothesis test conducted.

Table 4.48: Mean area burned (in percent), where villages are categorized based on acreage of olive groves and vineyards. Categories were formed based on the median acreage.

Variable	Observations	Mean	Std. Error	Std. Dev.	95% Conf. Interval	
Low olive grove acreage	24	.6653121	.0462883	.2267652	.5695575	.7610667
High olive grove acreage	23	.5138813	.0527156	.2528149	.4045559	.6232067
Low vineyard acreage	23	0.6131757	0.0564153	0.2705583	0.4961775	0.730174
High vineyard acreage	24	0.570155	0.0471276	0.2308774	0.472664	0.667646

At the 5% level of significance the data provide sufficient evidence to suggest that villages with higher olive grove coverage were burned at a lower level when compared to villages that had less olive groves. The relevant figures for area burned are 66% (for low olive grove coverage) and 51% (for high olive grove coverage). Results for vineyards are not statistically significant.

4.4 Summary - Discussion

The purpose of this chapter was to introduce the variables of the model and to present a preliminary analysis of the data. A series of t-tests was conducted in order to draw some initial expectations regarding the anticipated relationship between the dependent variable and each of the RHS variables. The results are summarized on table 4.49. It is important to point out that these findings are only the result of preliminary statistical analysis. They are not to be used as the basis for any final conclusions or policy recommendations. They represent simple comparisons between two variables without taking into account interactions amongst the full range of data. Their goal is to familiarize the reader with the data and to serve as a point of reference with the results from the estimation model that will be carried out on the following chapter. Conclusions can only be drawn from an econometric analysis that captures the full range of relationships between all the variables.

Table 4.49: Summary of findings based on the preliminary statistical analysis

RHS variables	Percent of area burned	Statistical significance
Day of the fire	(-)	No
Participation	(-)	Between low and medium participation
Fire crews	(-)	Between no and low presence
Operation of water bombers	(-)	Between low and high operation
Fire prevention	No pattern identified	No
Fire history	No pattern identified	No
Water availability	No pattern identified	No
Wind speed (Andravida station)	(+)	Yes
Wind speed (Amaliada station)	(-) (counter intuitive)	No
Humidity (Andravida station)	(-)	Yes
Humidity (Amaliada station)	(-)	Yes
Elevation	(+)	Yes
Slope	(+)	Yes
Population density	(-)	Yes
Road density	(-)	No
Olive grove acreage	(-)	Yes
Vineyard acreage	(-)	No

CHAPTER 5

REGRESSION ANALYSIS

5.1 Introduction

The purpose of the current chapter is to estimate a model that will predict the percent of area burned (PAB) of a settlement given that a wildfire has, at minimum, reached some part of the village boundaries. Two types of estimation techniques will be used. Initially we will employ Ordinary Least Squares (OLS) estimation. This is a rather conventional and widely used statistical method. Secondly, an attempt to address sample selection issues in the dataset by estimating a truncated model will be pursued.

5.2 Data analysis: a recap

As analyzed in chapter 4 our sample size is comprised of 49 settlements. Our dependent variable is the percent of area burned (PAB) in every village. Right hand side variables are grouped 5 different categories:

a) Field data: day the fire reached the village, water availability during the time that the fire was within the boundaries of the village, presence of fire crews, operation of water bombers, fire prevention efforts prior to the fire season, fire history of the village, order to evacuate the village, participation of local citizens in fire suppression (8 variables in total).
b) Meteorological data: wind speed and humidity from 2 different weather stations (Amaliada and Andravida; a total of 4 variables).
c) Topographical data: average slope and altitude for every village (2 variables).

d) Demographical data: population density and road density per settlement (2 variables).

e) Vegetation data: olive grove and vineyard density per village (2 variables).

5.3 Dropped variables

In total 16 candidate models were estimated (see appendix for a full presentation of all estimation results). The main reason for which such an extensive variety of estimations was carried out is mainly attributed to considerations regarding the accuracy of meteorological data. As noted in section 4.3.2 meteorological data from 2 different weather stations were available. Separate models were estimated with data from the two stations as well as models with average data on wind speed and humidity (i.e. average wind speed and humidity between the weather stations of Amaliada and Andravida). Finally, the information from the station of Amaliada was chosen based on the greater accuracy of the data[12]. Hence, data from the station of Andravida were dropped.

In addition 4 variables gathered form the field were also dropped. The "evacuation" variable was not included, given that, as analyzed in section 4.3.1.2, ordered evacuations were not always followed by civilians. Hence we were concerned that by including this variable in the regression we would add bias to the results. Furthermore, the presence of the villagers in the settlements and their engagement in fire fighting would be effectively captured by the "participation" variable.

The three remaining dropped variables "fire prevention", "fire history" and "water availability" had several missing observations and were subsequently dropped in an effort to avoid a decrease in the sample size and consequently the degrees of freedom of the

[12] Data from Amaliada and Andravida were recorded on a 10 minute and 3 hour interval respectively.

model. Note that when those 3 variables were included in the estimation, their coefficients were not statistically significant. Table 5.1 below presents the results of 3 out of the total 16 candidate models that were initially estimated.

Table 5.1: Estimation results with all 15 variables included.

	Model_1	Model_2	Model_3
	per_burn	per_burn	per_burn
water	-0.0024	-0.0041	-0.0039
	[0.0362]	[0.0384]	[0.0357]
f_crew	-0.0186	-0.0067	-0.0041
	[0.0436]	[0.0501]	[0.0459]
wat_bom	0.0412	0.0014	0.0084
	[0.0445]	[0.0540]	[0.0495]
day	-0.0929	-0.051	-0.0378
	[0.0618]	[0.0537]	[0.0544]
elev	**-0.0013**	**-0.0013**	**-0.0013**
	[0.0003]***	[0.0004]***	[0.0004]***
slope	**0.066**	**0.063**	**0.0637**
	[0.0129]***	[0.0140]***	[0.0132]***
pop_den	**-0.003**	**-0.0033**	**-0.0031**
	[0.0014]**	[0.0016]*	[0.0016]*
road_den	**0.0001**	**0.0001**	**0.0001**
	[0.0000]***	[0.0000]**	[0.0000]***
olive_den	**-0.738**	**-0.6001**	**-0.6072**
	[0.2136]***	[0.2572]**	[0.2308]**
vin_den	0.5683	0.4499	0.516
	[0.3892]	[0.4652]	[0.4451]
f_prev	0.019	0.0181	0.012
	[0.0429]	[0.0479]	[0.0461]
f_hist	-0.0257	-0.0101	-0.0121
	[0.0251]	[0.0288]	[0.0263]
wind_amal	0.0142		
	[0.0124]		
hum_amal	-0.0021		
	[0.0042]		
part	**-0.0917**	-0.0791	**-0.0898**
	[0.0445]*	[0.0465]	[0.0438]*
wind_andr		-0.012	
		[0.0360]	
hum_andr		-0.0047	
		[0.0036]	
mean_hum			-0.0069
			[0.0046]
Constant	2.4055	1.6639	1.3166
	[1.4401]	[1.3301]	[1.3102]
mean_wind			-0.0004
			[0.0098]
Observations	39	39	39
R-squared	0.7845	0.7484	0.773

Standard errors in brackets
* 10% significance; **5% significance; ***1% significance

All 3 models in table 5.1 were estimated using (OLS). Note that Model_1 uses weather data from the station of Amaliada, Model_2 data from the station of Andravida and Model_3 data that were obtained by averaging the observations between the two stations. As can be observed, sample size is reduced from 49 to 39. The reason is that the three variables that were later on dropped (i.e. "fire prevention, fire history and water) had several missing observations. In addition none of these variables demonstrated any statistical significance; therefore their removal would not lead to loss of important information. Notice that, as mentioned previously, the evacuation variable was not included in either of the models.

5.4 Estimation techniques

The use of the OLS technique did not address the issue of the sample selection rule that was analyzed in section 4.2. More specifically, while on the field villages that had a low PAB (i.e. less that 10%) were not surveyed. In those settlements, people were rather reluctant to talk about the fires. Given that the damage to their village was not significant, they did not consider the fires such an important issue (at least for their settlement). In addition, the quality of information that they would provide was not always reliable, since the small level of damage usually meant a low level of engagement on their part.

Figure 5.1 presents the frequency distribution of PAB in all 130 villages of the state of Elia that were affected by the fires of late August. By comparing it to figure 5.2 that presents PAB for the 49 sampled villages, one can observe a significant difference. The bar of the first class in figure 5.1 is significantly under-represented in the sample (i.e. figure 5.2). To address this issue a truncated model with a lower limit of 10% was used.

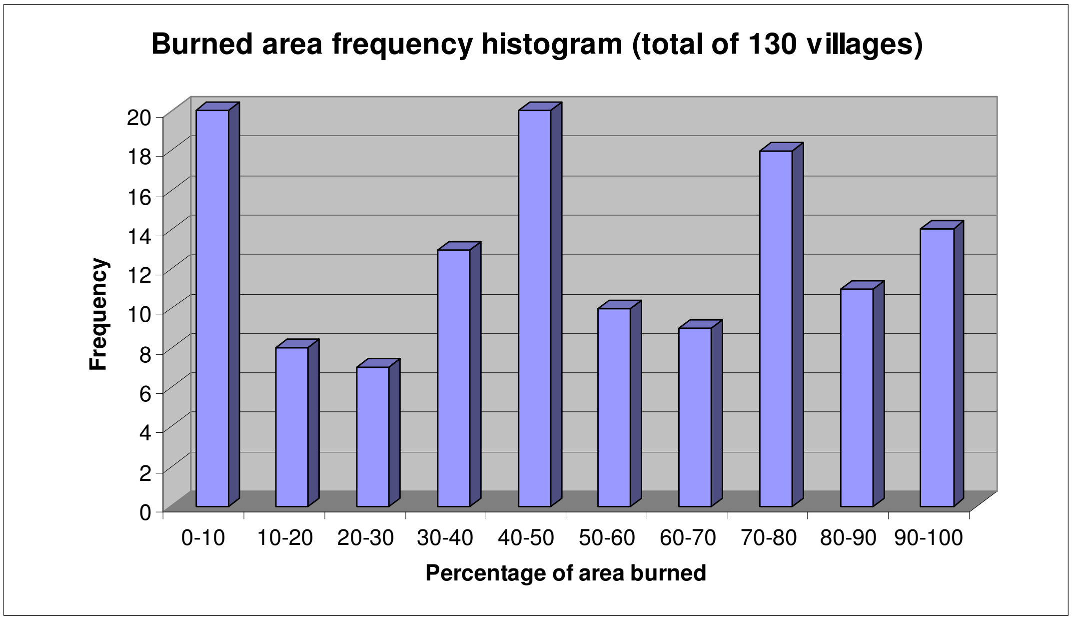

Figure 5.1: Burned area frequency histogram for the 130 villages in the state of Elia that were affected by the blazes of late August.

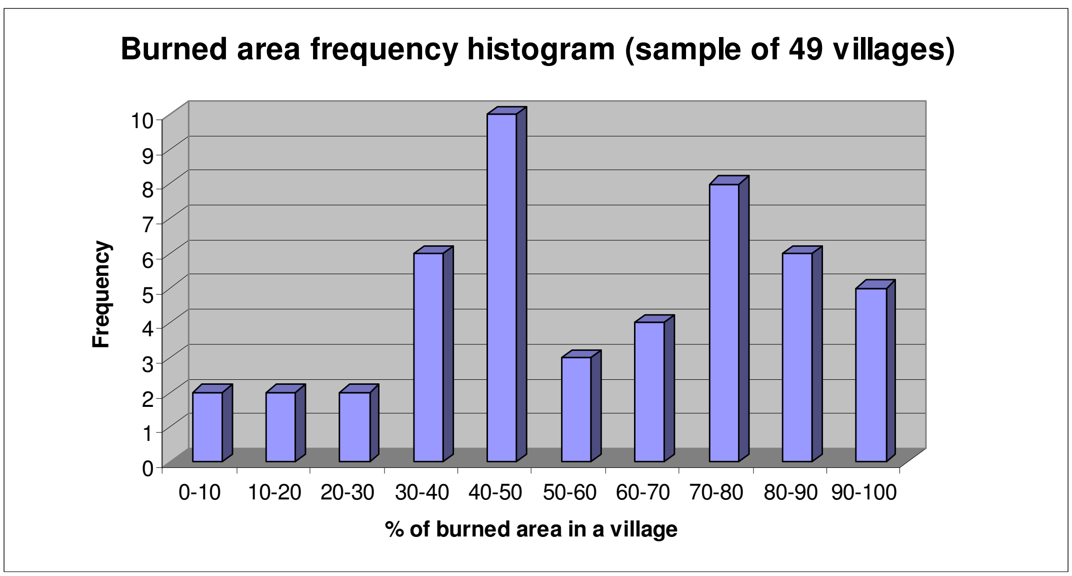

Figure 5.2: Burned area frequency histogram for the sampled villages

According to Maddala (1983) when a specific segment of the population is eliminated from a study then the appropriate estimation techniques is a truncated model. In our case, villages with PAB<10% were almost fully eliminated from the sample (only

2 observations were recorded within that class). If y=PAB and L=10% (i.e. the lower limit at which we truncate the data) then the truncation takes the following form: $y_i > L_i$.

We may assume that the population relationship between PAB and the vector of independent variables is of the following form:

$$y_i = \beta' x_i + u_i$$

where *y* is the PAB, *x* is a vector of independent variables (i.e. slope, elevation, wind speed, etc.), *i* is an index for villages and *u* are the disturbances assumed to be $ii(0, \sigma^2)$ (i.e. independently and normally distributed with mean of zero and a constant variance of σ^2).

Sampled villages were randomly selected amongst those whose satellite images were available (as analyzed in section 3.4.2).The density function of y_i is the truncated normal defined earlier:

$$f(y_i) = \frac{(1/\sigma)\phi[(y_i - \beta' x_i)/\sigma]}{\Phi[(L_i - \beta' x_i)/\sigma]}, \text{ if } y_i > L_i$$

$$f(y_i) = 0 \text{ otherwise}$$

Where $\phi(\cdot)$ and $\Phi(\cdot)$ are, respectively, the density function and the distribution function of the standard normal.

5.5 Regression models

The population regression equation for the truncated model is of the following form (please see Appendix for an analytical description of the variables):

$$\begin{gathered}\text{per\_burn} = \beta_0 + \beta_1\text{f\_crew} + \beta_2\text{wat\_bom} + \beta_3\text{day} + \beta_4\text{elev} + \beta_5\text{slope} + \beta_6\text{pop\_den} + \beta_7\text{road\_den} + \\ \beta_8\text{olive\_den} + \beta_9\text{vin\_den} + \beta_{10}\text{wind\_amal} + \beta_{11}\text{hum\_amal} + \beta_{12}\text{part} + \text{u}\end{gathered}$$

Results are presented in table 5.2[13]. Both the OLS and the truncated models are presented in an effort to facilitate comparison between the two. The models are statistically significant based on the F and χ^2 statistics for models (1) and (2) respectively. The R^2 for the OLS regression is 75.94%. In other words, 75.94% of the variation in PAB (i.e. the dependent variable) can be explained by the RHS variables. The Stata output for the truncated model does not provide an R^2 by default. For this model we calculated the squared correlation coefficient in an attempt to provide a comparable measure with the R^2 of the OLS regression. The resulting vale of this "proxy" R^2 is 75.15%, which is very close to the value of R^2 in the OLS model.

An important difference between the two models lies in the magnitude of the standard errors. As one can observe from table 5.2 the latter are significantly lower for all the coefficients of the truncated model. We can therefore conclude that the truncated model leads to an efficiency gain, which makes it preferable to the OLS technique.

Yet another difference between the two estimation techniques lies in the number of observations. The OLS regression uses 47 villages versus 45 used the truncated regression. In both models, two (out of our initial 49 observations) were dropped. Those were the following:

1) *The village of Lampeti*. Population data as well as information on olive and vineyard density were not available for this settlement. That is because, as highlighted in section 4.3.4 this particular settlement is administratively merged with the adjacent capital city of Pirgos.

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13 The statistical software used for model estimation was Stata Intercooled, version 9. Stata "do" files as well as "Log" files presenting the commands and detailed output of the regressions are included in a CD-ROM that can be found at the end of the thesis. Alternatively, the above can be made available by the author (e-mail address: nickziro@yahoo.com)

Table 5.2: Estimation results for the OLS (Model 1) and the truncated regression (Model 2).

	OLS (1)	Truncated (2)
	per_burn	per_burn
f_crew	-0.0272	-0.0448
	[0.0357]	[0.0322]
wat_bom	0.0254	0.0319
	[0.0361]	[0.0341]
day	**-0.114**	**-0.1105**
	[0.0479]**	[0.0416]***
elev	**-0.0012**	**-0.001**
	[0.0003]***	[0.0002]***
slope	**0.0671**	**0.0644**
	[0.0105]***	[0.0095]***
pop_den	**-0.0011**	**-0.0011**
	[0.0006]*	[0.0005]**
road_den	**0.0001**	**0.0001**
	[0.0000]***	[0.0000]***
olive_den	**-0.6207**	**-0.4966**
	[0.1797]***	[0.1589]***
vin_den	0.3299	0.3201
	[0.2500]	[0.2129]
wind_amal	**0.0196**	**0.021**
	[0.0097]*	[0.0087]**
hum_amal	-0.0007	0.0005
	[0.0036]	[0.0031]
part	**-0.086**	**-0.0633**
	[0.0372]**	[0.0324]*
Constant	**2.7627**	**2.5542**
	[1.1257]**	[0.9780]***
Observations	47	45
R-squared	0.7594	0.7515
F-value	8.94	
	(0.000)***	
Wald (χ^2)		115.44
		(0.000)***

Note that standard errors are presented in brackets. Significance levels are designated as follows: 10% level: *, 5% level: **, 1% level: *.**

2) *The village of Parapougi*. It does not belong within the administrative boundaries of the state of Elia and was thus dropped in order to preserve the consistency of the sample. Furthermore, data on olive grove and vineyard density were not available

for Parapougi. Thus including the observation in the sample would result in the appearance of missing variables.

Apart from those 2 dropped observations the truncated model also dropped an additional 2 observations that were below the 10% threshold (i.e. the villages of Skiloudia and Ploutoxori).

In an effort to facilitate the interpretation of the estimated coefficients, a log-log transformation of the truncated model was attempted (i.e. coefficients from log-log models can be easily interpreted as elasticities). However, the resulting fit of the model was not as satisfactory. Furthermore, errors were found not to be normally distributed and consequently the log-log model was dropped.

As stated above, the efficiency gain from the use of the truncated model makes it preferable compared to the OLS model. Therefore, we will analyze the results of the estimated coefficients of the truncated model in detail, presented in table 5.2, in order to facilitate their interpretation.

- *Presence of fire crews (F_crew)*: an increase of one level in the "presence of fire crews" category decreases PAB by 4.48%. The result, although intuitively of the expected sign, is not statistically significant at any conventional level.
- *Operation of water bombers (Wat_bom)*: an increase of one level in the "operation of water bombers" category increases the PAB by 3.19%. The result is counter intuitive and not statistically significant. One would expect that PAB would decrease as more waterbombers operated in a specific area.

- *Day*: a village that was reached by the fire on August 25th would have an 11.05% decrease in PAB relative to a village that was burned on August 24th. The result is statistically significant at the 1% level.
- *Elevation (Elev)*: an increase of one meter in the mean altitude of a settlement decreases PAB by .1%. The result is significant at the 1% level. As analyzed in chapter 4, vegetation moisture (which increases in areas of higher altitude) inhibits fire spread.
- *Slope*: a 1% increase in the mean slope of a settlement increases PAB by 6.44%. The result is significant at the 1% level.
- *Population density (Pop_den)*: a one unit increase in population density (measured in people per total area of a settlement) decreases PAB by .11%. The result is significant at the 5% level.
- *Road density (Road_den)*: a one unit increase in road density (measured in km of road network length over total area of a settlement in km^2) increases PAB by .01%. The result is significant at the 1% level. However, the magnitude of the coefficient is very small and rather counter intuitive. We would expect a negative relationship to exist between road density and PAB.

  As analyzed in chapter 4 the road density variable is comprised of 6 different categories of road types (i.e. single vs. two lane roads, loose surface vs. hard surface roads, car tracks and train tracks). The road density variable was created by adding up all the different types of road networks and dividing them by the total area of the village. In an attempt to isolate the individual effects of the 6 types of roads each road type was entered separately in the regression (i.e. we run a regression substituting total road network density with road density of only single lane loose surface roads, road density of only two lane hard surface roads, etc.). We also estimated models were the road density variable was comprised of combinations of different road types (i.e. density of all hard surface roads or all loosed surface roads or all single lane roads, etc.). The results in the vast majority of the cases showed a positive coefficient for the different types of road density variables. The only exception was the two-lane loose surface road that had an estimated negative coefficient, statistically significant at the 5% level. The intuition behind this result is that those types of roads are more likely to run through the forest and could act more efficiently as fire break zones, compared to hard surface roads that might run through areas that were not burned at all. Future work could possibly attribute a greater focus on the analysis of this parameter in order to determine a more robust result regarding the relationship between road density and wildfire spread.

- *Olive grove density* (Olive_den): a 1 unit increase in olive grove density (measured in olive grove acreage over total village area) decreases PAB by 49%. The result is statistically significant at the 1% level.
- *Vineyard density (Vin_den)*: a 1 unit increase (measured in vineyard acreage over total village area) in vineyard density increases PAB by 32.01%. The result is not significant at any conventional level. Furthermore, the sign of the coefficient is counter intuitive. We would expect a negative relation between vineyard density and PAB.

- *Wind speed as measured in the station of Amaliada (Wind_amal)*: a one km/h increase in wind speed increases PAB by 2.1%. The result is significant at the 5% level and of the expected sign.
- *Humidity as measured in the station of Amaliada (Hum_amal)*: a 1% increase in relative humidity decreases PAB by .05%. The result is not statistically significant at any conventional level.
- *Participation (Part)*: a one level increase in the "participation of villagers in fire fighting" category decrease PAB by 6.3%. The result is significant at the 10% level and of the expected sign.

In an attempt to summarize the findings of our model we could separate our variables in ecological and human affected ones. The coefficients of the ecological variables (i.e. wind speed, slope, altitude, day of the fire) were in their majority highly significant (with the exception of humidity) and of the expected sign. Villages on steeper slopes and lower elevations as well as settlements that were hit by the fires on the first day(s) were in greater danger. Furthermore, prevailing winds exacerbated wildfire spread.

As far as human affected variables are concerned, the results indicated several significant factors, mainly participation, population density, olive grove density and road density (although the latter variable had a counter intuitive sign). Wherever locals engaged in fire suppression efforts, fire spread was not as extensive. Had the authorities considered that fact instead of following indiscriminately evacuation strategies, then the outcome would have probably been different. By incorporating capable farmers in the abatement process fire spread could have been significantly reduced (Xanthopoulos, 2007b).

In addition, increased olive grove density inhibited fire spread. This effect could be attributed to several factors. Primarily, as argued in chapter 4, the land management patterns in the state of Elia, that require extensive weed removal from olive groves, contributed to the break up of fuel continuity. Furthermore, the importance of olive oil production in the states' agricultural market may have given an additional incentive to farmers for the protection of olive groves. Given constraints in data availability it is hard to disentangle the importance that each of the two above mentioned factors (i.e. break up of fuel continuity vs. additional effort on behalf of the farmers) had in reducing wildfire spread. However, this issue could be the focus of a future study regarding wildfire risk and vegetation coverage.

5.5.1 Test for error normality

A test for the normality of errors reveals that the disturbance term in both models (1) and (2) follows a normal distribution. More specifically, at any level of significance the data do not provide enough information to conclude that there is non-normal skewness or non-normal kurtosis or both. Results are summarized on table 5.3[14].

Table 5.3: Test for normality of errors

	Pr (skewness)	Pr(kurtosis)	Pr(omnibus)
Model (1)_OLS	0.853	0.529	0.8028
Model (2)_Truncated regression	0.682	0.949	0.9178

5.5.2 Testing for multicollinearity

A potential problem when estimating a model is the presence of multicollinearity. The latter arises when systematic relations exist amongst the explanatory variables of a

14 The set up of the test for the normality of the errors can be found in the Appendix.

model. There are two ways of testing for the presence of multicollinearity within a sample of data. One is to compute a correlation coefficient matrix. This will detect the presence of linear association between pairs of variables. According to a commonly used rule of thumb the researcher should suspect the potential existence of multicollinearity if the correlation coefficient between two variables exceeds .8 or .9 (Griffiths et al., 1993). Table 5.4 illustrates the correlation coefficient matrix for the explanatory variables in the model. Note that the only two variables with a strong linear association are elevation and slope with a correlation coefficient of .79

Another method for detecting the presence of multicollinearity is by calculating the Variance Inflation Factors (V.I.F.s). According to Chatterjee et al. (2000) a commonly used rule of thumb is one which sets a threshold of 10 for VIF values. Any VIF above that number provides evidence for the presence of multicollinearity. The latter could also exist when the mean of all VIFs is considerably larger than 1. Table 5.5 (on the following page) provides the VIFs form the OLS model. None is above the threshold of 10 and the mean is not considerably larger than 1.

Table 5.4: Correlation coefficient matrix

	Day	elev	slope	pop_den	road_den	olive_den	wind_amal	hum_amal
day	1.00							
elev	-0.44	1.00						
slope	-0.21	0.79	1.00					
pop_den	0.05	-0.47	-0.55	1.00				
road_den	0.19	-0.45	-0.48	0.40	1.00			
olive_den	0.15	-0.50	-0.34	0.23	0.26	1.00		
wind_amal	0.26	-0.12	-0.01	0.01	-0.03	0.10	1.00	
hum_amal	0.36	-0.13	-0.07	0.07	0.21	0.07	-0.58	1.00
part	0.51	-0.29	-0.16	0.13	0.07	-0.02	-0.02	0.11

Table 5.5: Variance Inflation Factors

Variable	VIF	1/VIF
elev	4.63	0.215937
slope	3.61	0.276817
day	3.32	0.301367
hum_amal	3.08	0.325178
wind_amal	2.91	0.343497
part	1.86	0.536813
f_crew	1.8	0.556395
pop_den	1.74	0.573245
wat_bom	1.53	0.652379
olive_den	1.5	0.665262
road_den	1.47	0.682144
vin_den	1.35	0.741265
Mean VIF	2.4	

5.5.3 Heteroskedasticity

Heteroskedasticity is yet another potential problem in model estimation. It exists when the variance of the errors is not constant. To test for heteroskedasticity we conducted a Breusch-Pagan (BP) test. According to the results we fail to reject the null hypothesis of no heteroskedasticity (i.e. constant variance of the error term) at any conventional level of significance.

5.6 Discussion-Conclusions

We will attempt a comparison between the findings of the preliminary statistical analysis carried out in chapter 4 and the estimation results from the model. Table 5.6 lists the results from the two different methods.

The majority of the relations are in agreement between the two methods. The only significant difference is in the case of the road density variable. Furthermore, the "day" variable would require further clarification and analysis. That is, we need to disaggregate between nature and human effects captured in that variable. As analyzed in chapter 4 the main intuition here is that as the days went on, authorities as well as citizens started overcoming the initial state of panic and responding more efficiently to the fires. However, it could also be the case that this change in response was encouraged by the decrease in fire severity. Unfortunately, the available data do not allow us to explore this distinction further.

Table 5.6: Comparison of findings

RHS variables	Preliminary analysis	Estimation results
Day of the fire	(-)	(-)*
Participation	(-)*	(-)*
Fire crews	(-)*	(-)
Operation of water bombers	(-) *	(+) (counter intuitive)
Wind speed (Amaliada station)	(-) (counter intuitive)	(+)*
Humidity (Amaliada station)	(-)*	(-)
Elevation	(+)* (counter intuitive)	(-)*
Slope	(+)*	(+)*
Population density	(-)*	(-)*
Road density	(-)	(+)* (counter intuitive)
Olive grove density	(-)*	(-)*
Vineyard density	(-)	(+) (counter intuitive)

Two human-affected variables are also of great importance; participation and olive grove density. Participation of local people in fire abatement seems to have important mitigation implications. One could argue that property owners have the highest incentive to protect their belongings, a fact that motivates them to engage in fire fighting. In the state of Elia, the motive was even higher, since agriculture is the primary economic activity. The above argument is partially confirmed by the data. More specifically from table 5.3 one can observe that the correlation coefficient between participation and vineyard density is .28. However, the relevant number that captures the relation between participation and olive grove density is -.02. Apart from a high motivation, villagers were in most cases capable to participate in abatement efforts, since most of them had faced wildfires in the recent past. It is important to note that participation was in most cases spontaneously generated and poorly organized. Almost none of the village level officials were aware of any evacuation strategy or fire fighting plan of action.

This issue holds an important policy implication. It is necessary for the state to engage in an education campaign with the aim of involving local communities in emergency plans of action. These plans, that should not be limited to wildfire mitigation, should make citizens aware of safety guidelines during emergencies, as well as informing them about how to best coordinate their community in order to prevent destructions. Survey participants argued on the usefulness of the following suggestion. Many villagers own tractors as well as excavating machines and bulldozers. In the case of emergency, local or state authorities, could potentially summon those machines and, given that their users have received prior training, utilize them as part of fire abatement efforts. The above suggestion of course requires that authorities have developed an effective resource allocating strategy and established sufficient organization and communication channels amongst all the parties involved (i.e. fire brigade, state leadership, police department, county mayors, village presidents, citizens, etc.).

Furthermore, olive grove density is yet another human-affected variable with significant implications. Estimation results suggest that increased olive grove density leads to lower lever of burned area. As argued in chapter 4 this could be attributed to ground fuel fragmentation. Additional analysis would be required at this point in order to validate the argument that plowed olive groves posses a lower wildfire risk compared to fields treated with the destructor. Intuitively the above argument sounds reasonable. After all, local fire officials encourage farmers to plow their fields in order to secure their property from fire damages. Nevertheless, the intensity of the August 2007 fires in Elia was such that in some cases even plowed olive groves were burned.

CHAPTER 6

POLICY RECOMMENDATIONS

6.1 Summary

Wildfires are an integral part of the natural life cycle of forests. It is of paramount importance that we learn to live with them and consider them as part of our lives. The best way to achieve this is to study and comprehend fires as fully as possible. Ecological factors are the primary drivers of fire occurrence and behavior. Nevertheless, during the past decades a strong link between wildfires and human factors is being developed. Social fire science is an attempt to understand the interactions between man and the natural phenomenon of fire, by incorporating several socio-economic parameters in traditional fire science. The scope and purpose of this project was to contribute to this emerging field of study, with specific reference to the case of Greece.

The Mediterranean basin has been historically one of the geographical regions most concerned with the issue of forest fires. A mixture of climatic conditions as well as the expansion of the Wildland Urban Interface (WUI) throughout many southern European countries in the basin has led to the gradual increase of wildfire occurrence. Greece is amongst those Mediterranean countries that has an increasing amount of it's forest acreage burning every year. A series of social and cultural factors (analyzed in chapter 2) have contributed to that fact. Most important amongst them is the abandonment of rural areas and forests by both citizens and state. Ever since the end of the Greek civil war (1949), but especially since the mid 1960s Greeks have been massively fleeing from the countryside and making their way to the large cities in search of employment. As a result forests, once a primary means for making a living, are now left unmanaged. What is more, legislative gaps and cases of corruption have historically allowed for housing development of burned forest land; a situation that motivated the practice of arson.

The summer of 2007 was the worst wildfire season ever recorded in the country's contemporary history. The state most severely hit was the Peloponnesian state of Elia. A sample of 49 villages were surveyed in an attempt to identify the main causes of the destruction that occurred. The findings identified villages in low altitudes and steep slopes as the ones most vulnerable to the risk of wildfire. Wind speed played a significant role in exacerbating the blazes. As far as human factors are concerned population density is negatively associated with wildfire spread. In addition, the more olive groves were located within the boundaries of a village the less damage the latter was found to have sustained. Finally, participation of local people in fire fighting also proved important.

It is critical to note that these results could not be used to drawn inferences for the entire population. The relative small sample size and it's limited geographic span pose constraints to any inference efforts. Nevertheless, the research method is there to propose the incorporation of new variables (i.e. human affected vegetation coverage, people's participation, presence of fire crews) in a model whose goal is to apply a more holistic approach to the forecasting of fire spread.

6.2 Policy recommendations

There is a series of potential policy recommendations that arise from the statistical analysis of the data gathered. The most important ones deal with the issue of local engagement and human affected vegetation coverage (i.e. olive groves).

The statistical analysis carried out in chapter 5 provided evidence to suggest that participation of local people in firefighting decreases the damage sustained by the wildfires. It is thus very important to educate and inform civilians regarding the issue of wildfire prevention and mitigation. In the vast majority of the villages surveyed there were no evacuation plans in place, let alone wildfire engagements strategies. In most cases villagers acted individually, rather than collaboratively, trying to save their houses or agricultural fields form the blazes. It is of paramount importance for states and municipalities to develop Action Plans that prepare people for the event of a wildfire and any other natural destruction for that matter. Being prepared and knowing what to do in the event of a forest fire is key in the effort to best protect oneself. Capable citizens should be given specific instructions as to how to best get involved in fire abatement, during a potential crisis. Such Action Plans would of course require the collaboration of different government agencies (i.e. forest service, fire brigade, police department, state officials, etc.). Once put in place, they should be effectively communicated amongst all interested parties within state and local communities.

Findings from the statistical model also demonstrated the fact that higher olive grove density resulted in lower wildfire damage. Of course, no one could ever suggest the expansion of olive groves as a wildfire mitigating method, since such a policy could lead to the application of a monoculture. What could be promoted though is the application of the proper land management techniques amongst farmer. As presented in chapter 4 there are different techniques for weed management within an olive grove. The use of the plough appears to be a safer option in terms of wildfire protection. Fire brigade officers advice farmers to use the plough instead of the "destructor" when weeding. However, this hypothesis needs yet to be verifying statistically on the field. A potential policy could provide motives to farmers, potentially in terms of subsidies, so that they would embrace this technique.

Our model explains a considerable amount of the variation in wildfire spread amongst the sampled villages. Nevertheless, just like with any other real world issue, there are certain aspects of the problem that cannot be captured numerically. Some of them (i.e. land registration problem, reallocation of wildfire abatement jurisdiction from the forest service to the fire brigade, increase emphasis on aerial firefighting, etc.) were addressed in chapter 2. In this final section we will attempt to draw policy recommendations pertaining to those issues.

So long as no specific land registration system exists in Greece, arsonists will always have a motive to set forest fires in order to create land available for development. Efforts to limit the growth of infrastructure are historically inhibited by the lack of clear identification of the boundaries of forest land as well as cases of corrupt public officials. A land registration plan would eliminate any ambiguities with respect to what is considered forest land and what is not. That would be the first important step to securing the preservation of Greek forests.

Since 1998 the Greek wildfire management system has been divided amongst the Fire Brigade (who is since then responsible for suppression efforts) and the Forest Service (responsible of prevention and post-fire management). This fragmentation of jurisdictions has done little to reduce wildfire risk. For the last few years the Forest Service has been gradually and increasingly becoming understaffed. Thus, prevention efforts are now limited to the maintenance of forest roads. Fire break zones are scarce and the removal of biomass is hardly practiced. The subsequent accumulation of combustible fuel increases wildfire risk every year. The authorities have to reconsider the importance of wildfire prevention strategies and allocate financial and human resources accordingly.

At the same time the Greek state has being allocating an ever increasing amount of funds to the purchase of aerial fire fighting equipment. While, the latter is certainly a vital part of fire suppression it is certainly not the only weapon in the fight with fires. As fire fighting pilots themselves admit, fires are not extinguished from the air. The presence of ground personnel is equally if not more important. Contrary to what one would expect, ground fire fighters (also responsible for urban fires, helping people involved in car accidents, etc.) receive little training in combating forest fires. Most of their knowledge comes from experience. In addition, fire fighter unions have been over the years expressing the view that the equipment they are provided with is of low quality.

Greece has to reconsider all aspects of it's wildfire management strategy. First and foremost it has to remove any legislative gaps that inhibit the preservation of valuable natural ecosystems as well as combat cases of political corruption. Prevention should become a key part of wildfire management. The technological expertise is available; it's only a matter of applying the methods most appropriate for Greece. Furthermore, a holistic wildfire risk assessment should be carried out for all areas of the country; one that will incorporate not just ecological variables, but also socio-economic parameters. Community Action Plans should also be put in place. Their purpose will be to inform and prepare community members with regards to the best possible reaction in the event of a fire. Finally, the focus of fire suppression needs to be shifted towards the empowerment of ground forces. The above steps could help secure both the country's citizens as well as it's forest resources from the risk of wildfires.

On a final note we conclude that public policy should consider a more holistic approach to wildfire management; one that would incorporate the "human-fire" interactions more thoroughly and balance the importance of ecological variables and social parameters in both wildfire prevention and mitigation.

APPENDICES

APPENDIX A

PRE AND POST FIRE PHOTOGRAPHS FROM THE STATE OF ELIA

Figure 2: The village of Makistos (county of Zacharo) before the fires. Source: www.zacharo.gr

Figure 3: The village of Makistos after the fires.

Figure 4: The village of Smerna before the fire. Source: www.zacharo.gr)

Figure 5: The village of Smerna after the fire.

Figure 6: Before and after the fire photographs in the outskirts of the village of Miraka. Source: www.helpmiraka.com

Figure 7: Kronios hill (in the archeological site of Ancient Olympia) before the fire. Source: GoogleEarth.com

Figure 8: Kronios hill on fire. Source: GoogleEarth.

Figure 9: Kronios hill after the fire.

Figure 10: The archeological site of Ancient Olympia, before and after the fires. Source: Dr. Efthimios Lekkas (2007).

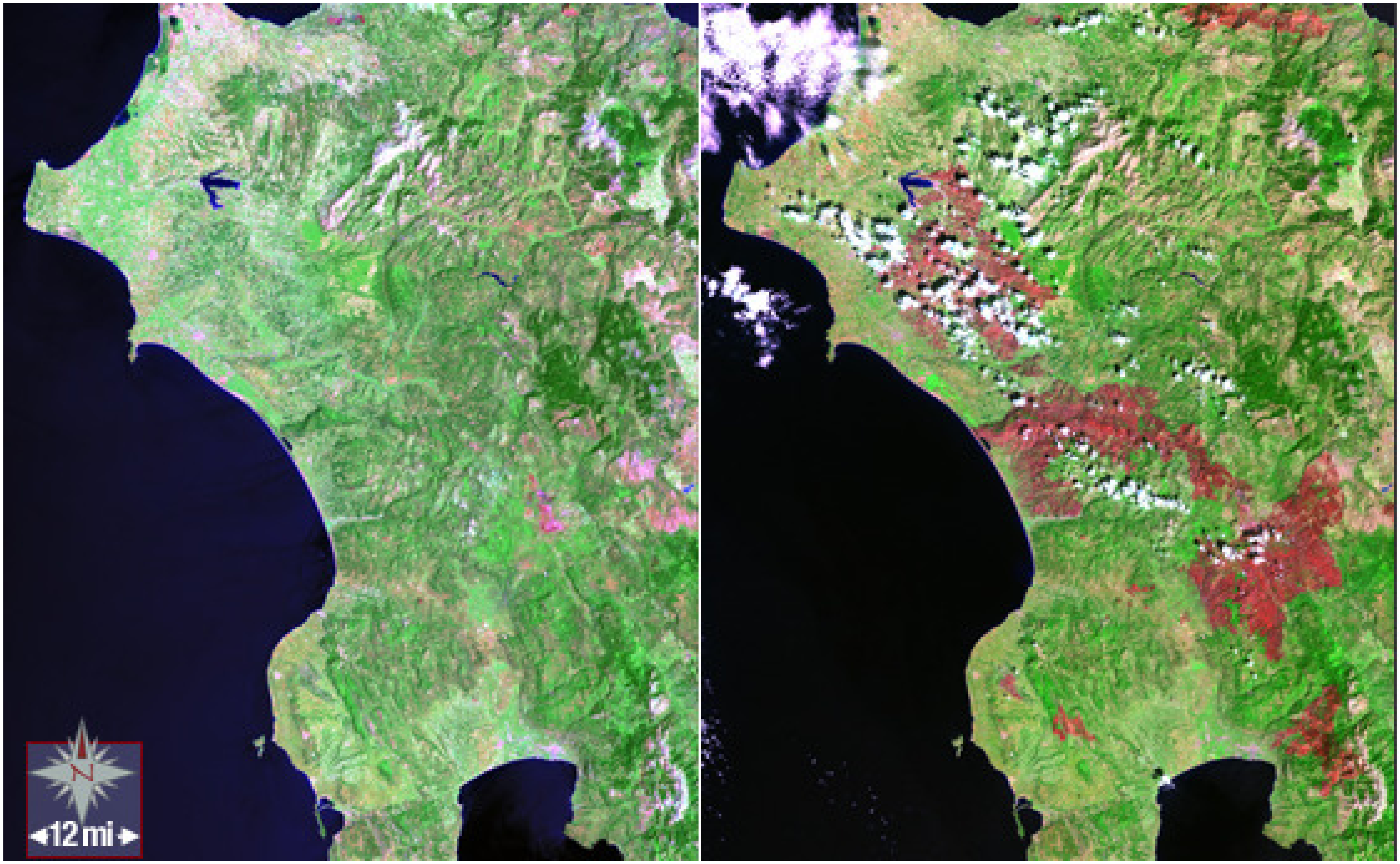

Figure 11: A Landsat image of western Peloponissos before and after the fires. The red areas represent burned land. Source: NASA (2007)

Figure 12: A Turkish Canadair CL-215 that was part of the international assistance offered to Greece during the August 2007 wildfires. Source: Ioannis Kapakis, Hellenic Forest Service (2008)

Figure 13: A Greek PZL plane, based at the airport of epitalio. Source: Pigi Giakoumelou (2007)

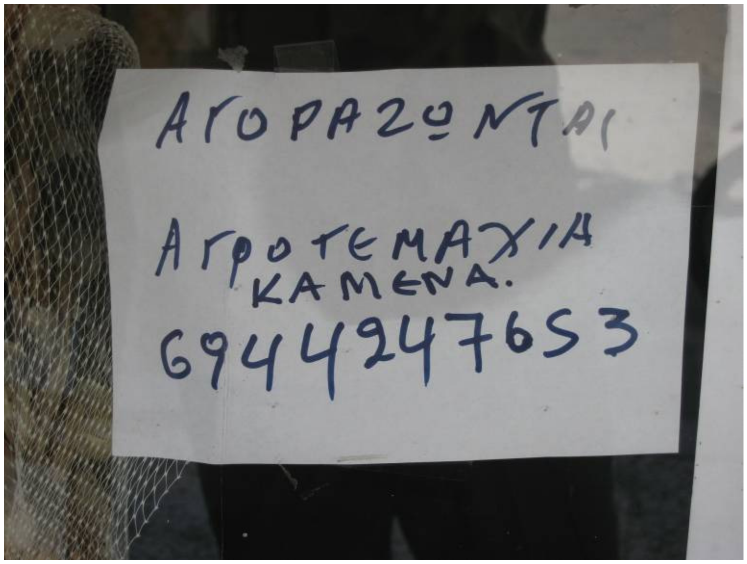

Figure 14: The sign in a village of Elia reads: "Buying burned land parcels". The developers were quick to take advantage of the destruction. Source: Dr. Efthimios Lekas (2007)

Figure 15: A burned house in the village of Smerna. The painting was preformed by a group of boy scouts that conducted volunteer work after the fires in order to assist villagers. It reads: "The trees are our hearts. Hope can grow again."

APPENDIX B

STATISTICAL TESTS

Test for normality of the errors

Skewness test

If $\sqrt{\beta_1 > 0}$ then this implies that our distribution is skewed to the right (D'Agostino et al., 1990; 317). Unlike SAS, Stata only reports the P-value of $\sqrt{\beta_1}$.

We are going to conduct a hypothesis test in order to test for skewness.

Ho: $\sqrt{\beta_1}$ (skewness parameter) = 0

Ha: $\sqrt{\beta_1}$ (skewness parameter) $\neq 0$

Kurtosis test

If $\beta_2 < 3$ then this implies that our distribution is unimodal but with thiner tails than the normal distribution (D'Agostino et al., 1990; 317). We are going to conduct a hypothesis test in order to test for kurtosis.

Ho: β_2 (kurtosis parameter) = 3

Ha: β_2 (kurtosis parameter) $\neq 3$

Omnibus test

Ho: there is no non-normal skewness or no non-normal kurtosis or both

Ha: there is at least one of the above (i.e. either non-normal skewness or non-normal kurtosis or both)

Breusch-Pagan test

The BP test statistic is given by the following formula:

$$BP = \frac{ESS}{2\tilde{\sigma}^4},$$

Where *ESS* is the Estimated Sum of Squares (note that TSS=ESS+RSS, i.e. Total Sum of Squares = Estimated Sum of Squares + Residual Sum of Squares) and $\tilde{\sigma}^4$ is the variance of the model squared.

APPENDIX C

VARIABLE EXPLANATION

perc_burn: the percentage of the total area of the village that was burned by the wildfire

f_crew: presence of fire crews. 0 none, 1 low, 2 high

wat_bom: operation of waterbombers. 0 none, 1 low, 2 high

day: the day a village was reached by the fire. 24th, 25th 26th or 27th of August

elev: mean altitude of a village measured in meters

slope: the mean slope of the village in %

pop_den: population density, i.e. population per total area in sq_km

road_den: road density, i.e. road length divided by total area in sq_km

olive_den: olive grove density, i.e. % of total area of th village covered by olive groves

vin_den: vineyard density, i.e. % of total area of the village covered by vineyards

wind_amal: wind speed in km per hour measured in Amaliada weather station

hum_amal: relative air humidity in % measured in Amaliada weather state

part: participation of locals in fire suppression; 0 low, 1 medium, 2 high

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