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ORIGINAL PAPER

Assessment of extreme weather events on transport networks: case study of the 2007 wildfires in Peloponnesus

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Abstract This paper deals with the 2007 wildfires that hit Peloponnesus, the southern peninsula of Greece, presenting an overview of the impacts in terms of infrastructural damages and human injuries and losses. Network performance and components' criticality analyses are used to assess the effects of the fires in vehicular traffic and the overall transport network. The crisis and emergency management of the event are discussed in depth, highlighting potential gaps and possibilities for future improvement. The paper concludes with a presentation of the adaptation measures that succeeded the event in terms of recovery plans, national efforts on fire prevention programs and wildfire management.

Keywords Extreme weather event impacts · Transport networks · Peloponnesus 2007 wildfires

1 Introduction

The increasing frequency of extreme weather events due to climate change has been widely studied in the literature (Rosenzweig et al. 2001; Monirul and Mirza 2003). In addition, the Intergovernmental Panel on Climate Change identified that major impacts of climate change are quite likely to occur "via changes in the magnitude and frequency of extreme events, which trigger a natural disaster or emergency" (IPCC 2007a, b). Most of these studies focus on the detailed statistical analyses of trends in extreme weather and climate events based on yearlong observations (Meehl et al. 2000; Easterling et al. 2000). They stated that the impacts of climate change might become more severe in the coming years

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due to the frequency of extreme weather events rather than the overall change in the "average" climate. Possible extreme weather events include wind gusts, snowfall, blizzard, heavy precipitation, heat waves and cold waves among others.

During the 2007 summer, extremely high temperatures were recorded in Greece, particularly during August. The country was hit by three consecutive heat waves (46 °C) which, along with the strong winds and the low relative humidity (9 %), resulted in forest fires breaking out. The region of Peloponnesus in the southern part of the country was mostly affected, especially between the 24 and 27 of August. The toll on human losses, natural disasters and infrastructure damages was heavy during the peak period of the event. According to the European Space Agency (ESA), Greece has experienced more wildfire activity during the summer of 2007 than other European countries have over the last decade (ESA 2007). In total, over 8,933 fires have been recorded in the country following the third heat wave the country had experienced in that period (EFFIS 2007). The mountainous southern peninsula of Peloponnesus was the worst affected region. The strong winds and the lack of precipitation in the area further increased the intensity of the blazes and supported the propagation of the event.

The aim of the paper is to present an overview of the wildfires' impacts in terms of infrastructural damages and human injuries and losses and to assess the wildfires' effects on the transport sector in terms of network performance. In addition, the crisis and emergency management of the event is discussed, highlighting potential gaps and possibilities for future improvement. Finally, the paper examines the adaptation measures that succeeded the event in terms of recovery plans, national efforts on fire prevention programs and wildfire management.

2 Case study description

Peloponnesus is located in southern Greece and comprises 7 prefectures. Figure 1 highlights their location in the national context. The most populated prefecture within the Peloponnese region is that of Achaia, with 331,316 people, while the region's total population is close to 1,165,147, within a total area of 21,386 km^2.

Table 1 summarizes the findings of the annual European Forest Fire Information System (EFFIS) report with regard to the number of fires and the affected area in Greece. EFFIS reports that 1,477 fires broke out in the Peloponnese region in 2007, burning 10,196 km^2 of land, 6,633 km^2 of which were protected forests and natural areas (EFFIS 2007) and killing thousands of animals (WWF 2007).

Figure 2 depicts the percentage of total burnt area per prefecture within the Peloponnese region. The prefecture of Ileia was affected the most during the 2007 wildfires.

The most severe fires broke out on August 24 and expanded rapidly until they were put out in early September. During the 2007 summer period, 68 people were killed, while another 2,094 people were injured (Statheropoulos 2008). Table 2 provides detailed information on the number of patients admitted in Peloponnese hospitals and medical centers and the respective cause of admission.

Six months after the events, a study was conducted by the Greek National School of Public Health which included random participants living in the affected and neighboring villages and concerned the subjective perception of their health status. The study revealed that both groups considered their health status better in the previous year and that the "fire" group experienced higher psychological distress thereafter (Papanikolaou et al. 2011).

Apart from the health sector, the impacts on residences and other infrastructure were also severe. A total of 847 residences were destroyed by fires in Greece, the majority of

Fig. 1 Location of Peloponnesus in Greece

Table 1 Number of fires and total burnt area (km^2) during the summer of 2007 (EFFIS 2007)

	Total number of fires	Total burnt area (km^2)	Wooded burnt area (km^2)
Region of Peloponnese	1,477	10,196	6,633
Other regions	7,446	211,860	129,930

which were located in Peloponnesus. Table 3 provides aggregate information regarding different types of infrastructure that were burned during the summer of 2007.

Concerning the economic impacts of the fires, no cost tool was available for its calculation. The estimation for the cost of the damages for the 500,000 people affected was close to 3 billion euros according to European sources (Davidson 2007), while other moderate estimations have found it to be close to 2.2 billion US dollars (USAID 2007). The overall operational costs were estimated as 600,000 euros (Michaletos 2007) as 20 % of the country's olive trees were located within the affected Peloponnese region, with the area representing 4.5 % of the nation's annual GDP (Davidson 2007). In addition to the direct costs of the events, the cultural tourism sector was also hit, since the blazes reached the proximity of the Ancient Olympia and affected a series of accommodation units (Tatoulis 2011).

3 Transport sector impacts

The importance of assessing the impacts of climate change on transport networks has been discussed by various researchers (Koetse and Rietveld 2009; Mitsakis et al. 2013). This has

Fig. 2 Percentage of burnt area in the Peloponnese region

also been recognized at a national level by the study on the environmental, financial and social impacts of climate change in Greece by the Bank of Greece (2011), which dedicated a section to the assessment of the impacts on Greece's transport networks (Giannopoulos et al. 2011). The study focused primarily on identifying the vulnerability of the transport system, the estimation of the demand for transport, the quantification of adaptation costs associated with various climatic scenarios and the formulation of measures and transport policies for coping with climate-change-related impacts on transportation networks and modes.

In the next section, the impacts of the wildfires on the transport network of Peloponnese are assessed.

3.1 Network and model description

The network used for the purpose of this paper consists of a detailed representation of the urban and regional road network of Peloponnesus, based on open-source GIS, fused with traffic parameters. The network consists of 178,734 directed road links and 70,137 nodes. The road links contain information about the number of lanes, the road type and its hierarchy in the network, width, length, free-flow speed, design capacity, direction and allowed transport systems. The nodes contain detailed information about the junctions' geometry, allowed movements and control type of the node. The network consists of 164 traffic analysis zones, the centroids of which are connected to physical nodes of the road network via 1,334 connectors, according to their accessibility index (Friedrich and Galster

Table 2 Health impacts in the Peloponnese region during the summer of 2007 (adapted from Stathero-poulos 2008)

Date	Respiratory problems	Ocular problems	Burnings	Cardiopulmonary problems	Number of patients	Deaths
17/08	20	2	3	6	50	0
18/08	19	4	1	13	45	0
19/08	17	4	2	16	59	2
20/08	26	5	1	19	74	0
21/08	29	3	2	18	70	0
22/08	18	2	3	25	72	0
23/08	28	3	3	15	92	0
24/08	52	9	14	14	115	0
25/08	149	68	28	8	285	45
26/08	79	64	15	14	199	1
27/08	76	21	14	18	159	7
28/08	50	15	8	18	115	0
29/08	21	4	6	18	70	1
30/08	34	4	6	18	81	0
31/08	30	5	5	11	80	1
1/09	17	6	9	14	67	0
2/09	14	4	0	14	38	0
3/09	21	1	4	12	63	0
4/09	18	5	4	11	60	1
5/09	26	2	5	20	72	1
6/09	16	3	1	13	50	0
7/09	10	0	2	13	35	0
8/09	10	1	2	9	38	1
9/09	17	0	1	16	45	1
10/09	18	5	0	14	60	0

2009). In order to assess the impacts of the wildfires in the transport sector, a transportation model has been developed for the region of Peloponnesus, with transport planning software (Friedrich 1999). The demand side is comprised of 24 hourly Origin–Destination (OD) matrices for the days of the wildfires (24/08–28/08), developed within the European Project "Transtools" (Transtools 2005). The obtained OD matrices are corrected using hourly traffic counts from 76 locations across the Peloponnese region, during August 2008. The OD matrix correction is performed with a fuzzy set-based matrix correction procedure (Rosinowski 1994). The upper-level user equilibrium traffic flow estimation, known as the traffic assignment problem, based on Wardrop's user equilibrium principle (Wardrop 1952), is solved with an implementation of the Linear User Cost Equilibrium algorithm (Gentile and Noekel 2009), with an average goodness of fit of 0.91.

3.2 Impacts

The vehicular traffic was most affected during the fire events of summer 2007. While fires mostly destroyed forests and farmland areas, they significantly influenced traffic

Table 3 Burnt infrastructure during the summer of 2007 (Statheropoulos 2008)

Region	Prefectures	Residences		Public infrastructure		Other	
		Total damage	Partial damage	Total damage	Partial damage	Total damage	Partial damage
Region of Peloponnesus	Arkadia	185	110	6	3	157	171
	Korinthos	3	0	1	0	10	5
	Ileia	524	238	30	12	498	233
	Lakonia	8	33	0	0	90	32
	Achaia	193	62	4	0	132	145
	Messinia	95	40	4	2	33	8
Total region of Peloponnesus		1,008	483	45	17	920	594
Other regions	Evia	31	245	0	2	29	95
	Etoloakarnania	1	2	0	0	0	0
	Attica	0	4	0	0	0	0
National total		847	672	41	19	817	544

circulation due to various link closures and affected the operability and functionality of the national and local road network. Between the 24 and 27 of August, the event peaked in terms of severity and seriously affected the rescue services. Figure 3 depicts the hourly propagation of the event in terms of closed road network in kilometers.

During August 25, the fires rendered 1,054 km of road network out of use, with the events and their impacts on the road network gradually declining afterward. Figures 4, 5, 6 and 7 visually present the progress of the road network closures in 4-h intervals for the period between the 24 and the 27 of August 2007, based on satellite earth observation data (Maurer et al. 2012).

Figure 8 depicts the occurrence rate of each closed link of the road network for the above-mentioned 4-day period. Since the satellite earth observations of the events were recorded and updated in hourly intervals, each occurrence value represents the hourly duration each link was closed for.

Figure 9 depicts the efficiency of each road network link that closed during 8 and 9 pm on August 26. The methodology for obtaining the efficiency of each link is based on Nagurney's Unified Network Performance Measure (Nagurney and Qiang 2008) and deals with the identification of the most important links related to the efficiency within a transport network.

The steps of Nagurney's methodology are the following:

- Step 1: The Origin–Destination demand matrices are assigned on the road network
- Step 2: Network efficiency is computed

$$\varepsilon = \varepsilon(G, d) = \frac{\sum_{w \in W} \frac{d_w}{\lambda_w}}{n_W} \quad (1)$$

where ε denotes unified network performance measure, G denotes the network topology (links, nodes), d denotes the demand vector (O–D pairs), W denotes the set of O–D pairs, d_w denotes the demand of O–D pair w, λ_w denotes the disutility of O–D pair w (travel time) and n_W denotes the number of O–D pairs for G

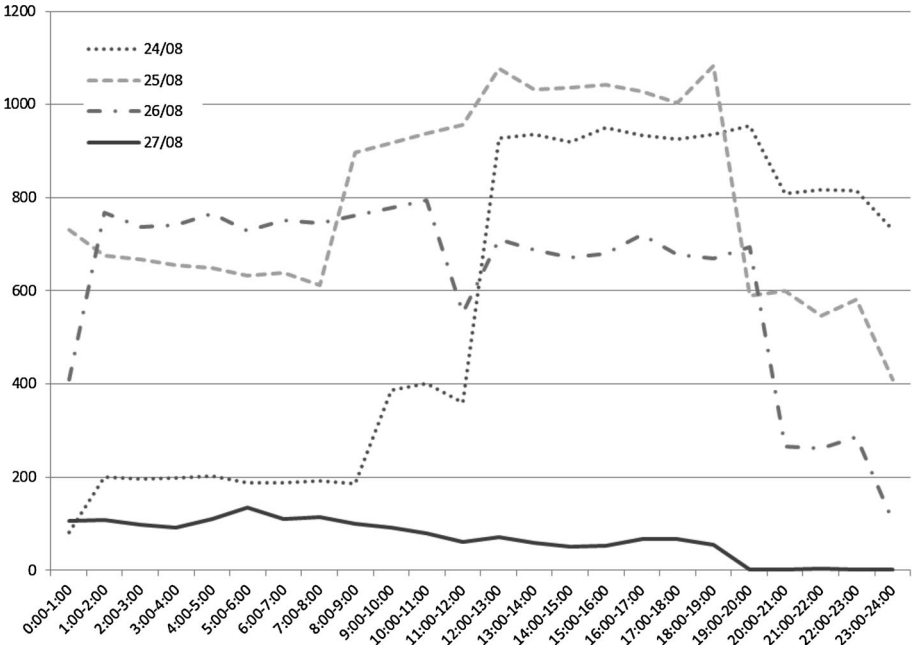

Fig. 3 Length of closed road network (in kilometers) per hour during the 24 and 27 of August

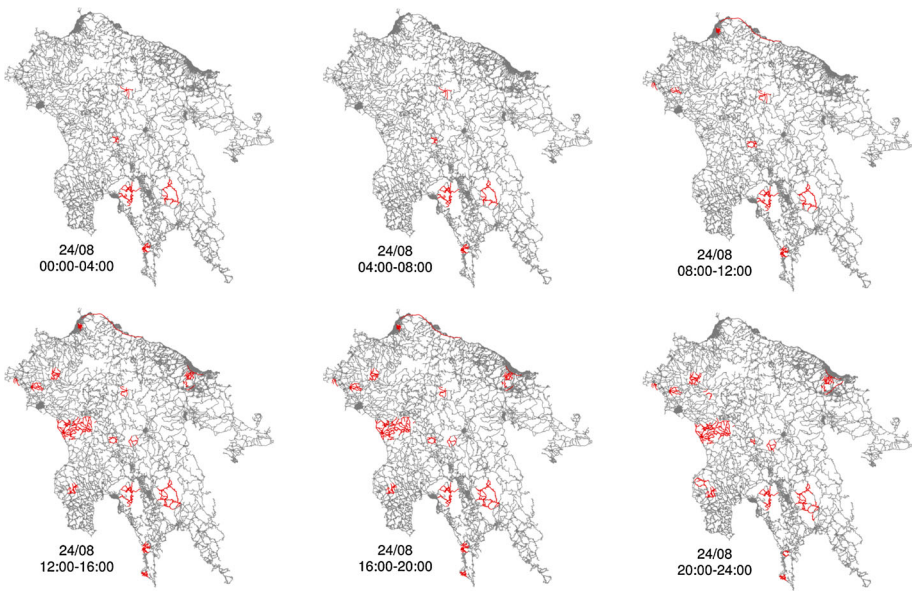

Fig. 4 Fire propagation during the 24 of August (Maurer et al. 2012)

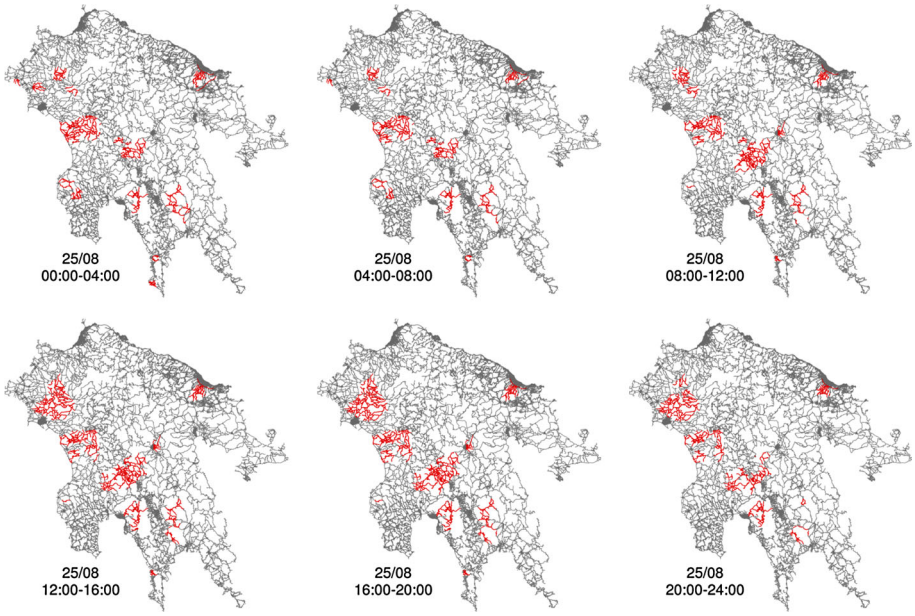

Fig. 5 Fire propagation during the 25 of August (Maurer et al. 2012)

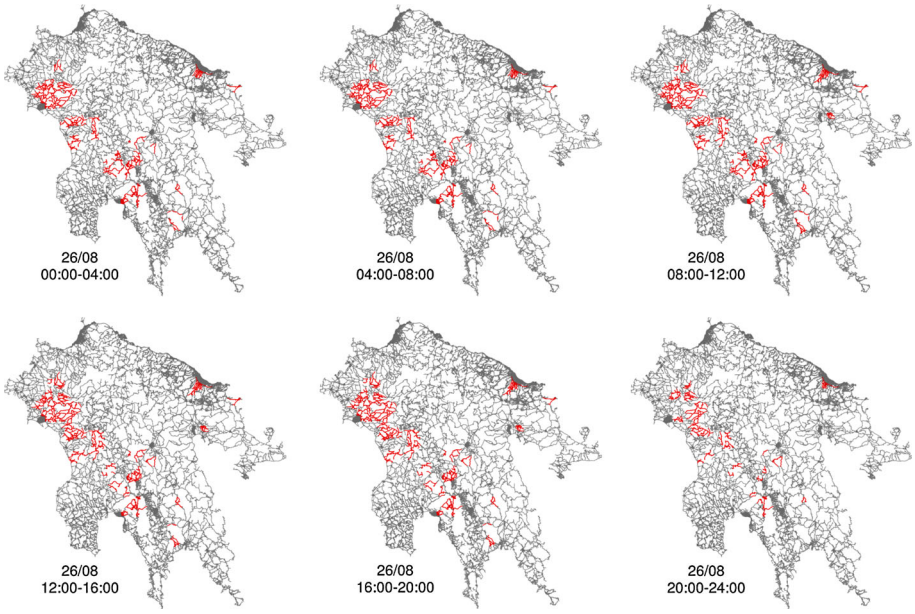

Fig. 6 Fire propagation during the 26 of August (Maurer et al. 2012)

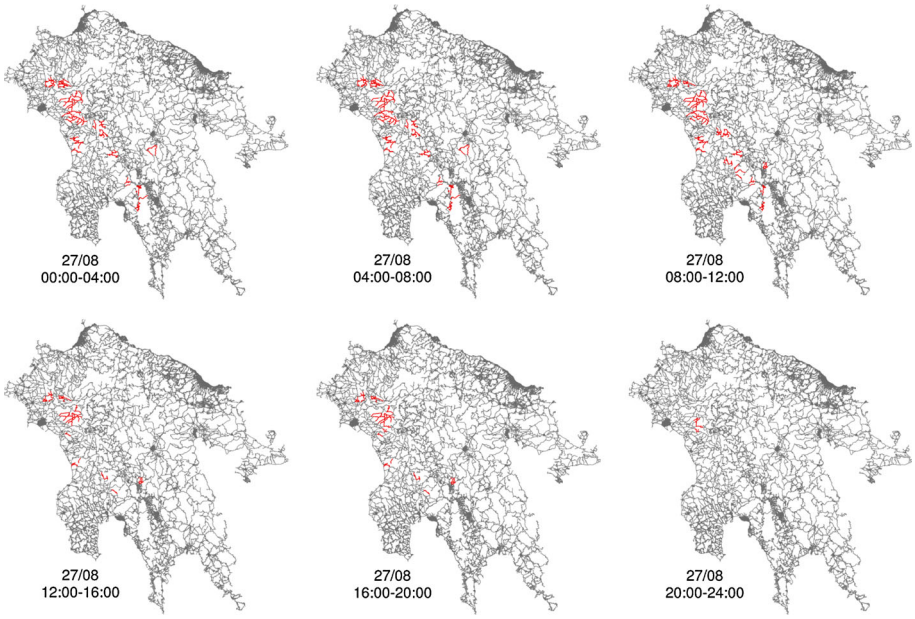

Fig. 7 Fire propagation during the 27 of August (Maurer et al. 2012)

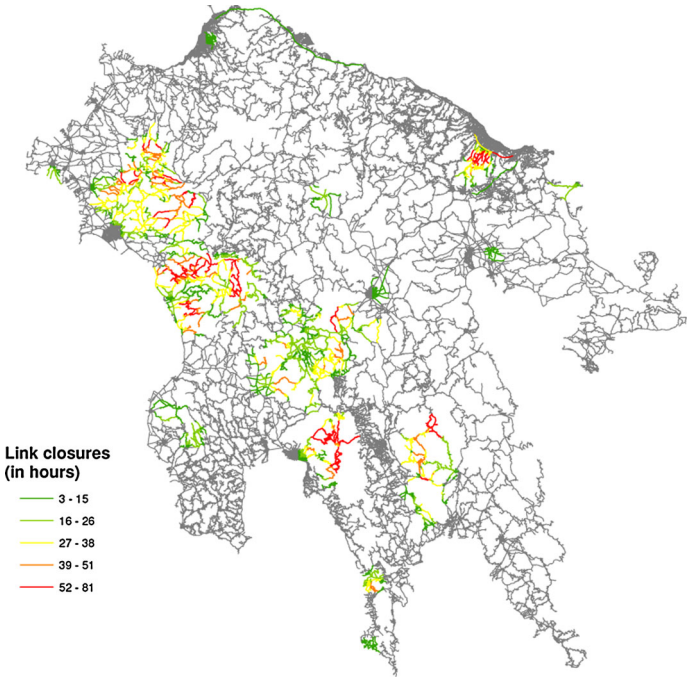

Fig. 8 Hourly link closures for the period between the 24 and 27 of August 2007

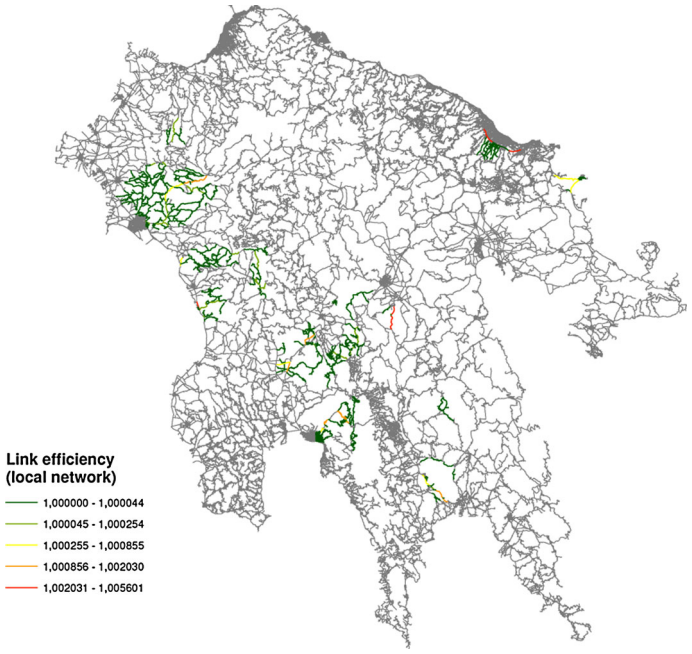

Fig. 9 Link efficiency in the local network of Peloponnesus

- Step 3: One link of the network is removed, and ε is computed again. Iteratively, this process is repeated for each link of the network in order to compute ε for each removed link.
- Step 4: The importance of each network component (link) is computed

$$I(g) = \frac{\Delta\varepsilon}{\varepsilon} = \frac{\varepsilon(G,d) - \varepsilon(G-g,d)}{\varepsilon(G,d)} \tag{2}$$

where $G-g$ is the resulting network after component g (link) is removed from network G. This criticality index for each link (I) represents the difference of the network's efficiency after the link(s) removal in relation to the initial (normal) condition of the network.

This exercise was conducted at the local level of the road network, in order to determine the impact of the closed links and their effect on the overall traffic circulation. The higher the efficiency values of the closed link, the more severe the effect it has on the network.

A similar analysis has been conducted for the national road network of southern Peloponnesus, in an effort to identify the importance of each link and the extent to which the network would have been affected, had it been closed due to extreme circumstances. The outcomes are presented in Fig. 10.

These analyses are important at a planning level, as they provide authorities with a tool that identifies the network components (road links) whose operation has to remain uninfluenced, especially in cases of extreme weather events. As such, this tool can assist public authorities in preventing or limiting the negative impacts attributed to road closures, by ensuring traffic circulation through the identified critical road links.

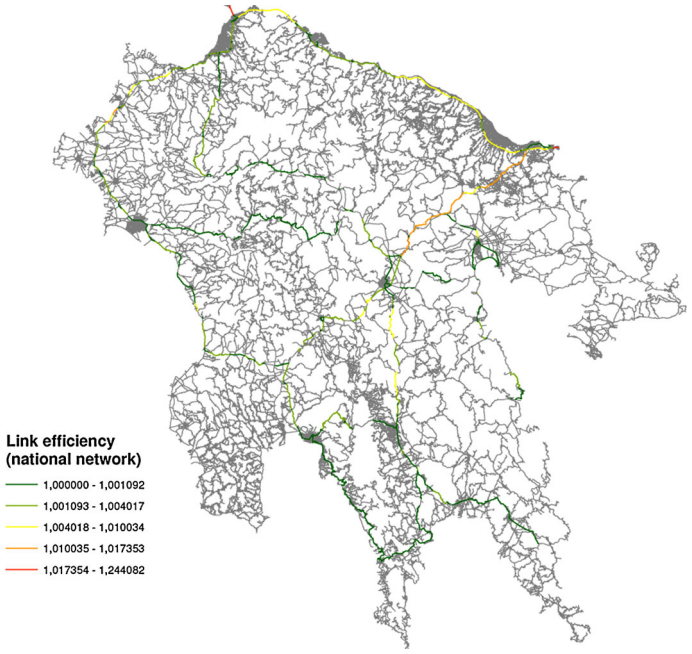

Fig. 10 Link efficiency in the national road network of Peloponnesus

4 Crisis and emergency management

The actors involved in response to the fires that occurred in the summer of 2007 have been the following:

- The Greek State
- The European Joint Civil Protection Mechanism
- The Greek Forest Service
- The Fire Brigade
- The local forest officers
- The General Secretariat of Forests and Natural Environment
- The Hellenic Air force
- The Army
- The volunteers
- The Police

The communication between all respective actors and emergency responders was established through handheld and on-board vehicle radios and cell phones.

4.1 Ground and aerial means

The fires' intensity and the need for intervention by the Fire Brigade did not allow fire crews to keep track of and record the beginning of the majority of the fires, beyond those that occurred during the first day. As stated in Zirogiannis report (Zirogiannis 2009), the fire department records of the capital city of Ileia's prefecture only reported the 6 initial

blazes of the first day. After those initial fires, the Fire Brigade could not record the occurrence of the fires that followed. As a result, when the event propagated in space and time, reaching more inhabited locations, fire fighters would respond based on the level of threat perceived (Zirogiannis 2009). According to the same report, which included field interviews of civilians and authorities, the officers in charge of the fire stations in Ileia's prefecture received hundreds of calls pleading for assistance during the 4-day period. Based on the capacity of the prefecture's fire department in personnel and infrastructure, as well as the fact that approximately 60 % of the villages in Ileia were hit by fires, fire-fighting personnel was inadequate during this period (JCICCH 2010). Approximately, 300 fire fighters equipped with 60 vehicles were responsible for handling the majority of the cases. Moreover, the four aircrafts destined to aid the operations, although initially stationed in the airport of Andravida (within Ileia's prefecture), had to assist the fire fronts in other prefectures during the same 4-day period. Ileia's ground firefighting forces were reinforced both by other Greek fire fighters and foreign volunteers. However, this help often proved to be fruitless since fire fighters originating from other places than the prefecture itself could not significantly contribute to the suppression efforts. This was the case because these non-local fire fighters were not acquainted with the local terrain, the landscape and the prevailing conditions in the area (winds, etc.). For this reason, they were often reluctant to drive fire trucks within the local forest as they did not know whether this could lead to a dead end. In addition, their efforts were hindered by the lack of knowledge concerning the exact location of water refueling points. As suggested in the case of fires' suppression, the disposal of information on such factors is a matter of experience (acquired from local fire crews working in the area for extended time periods) and its importance is decisive in the success of the suppression efforts. After the incident in Artemida, where 9 people lost their lives due to a road accident involving a fire truck and evacuation traffic, resulting to the road being blocked and people being trapped, the main concern of the authorities was to protect human lives and residences. According to Zirogiannis, it was often the case that a fire truck would arrive at a threatened location with orders to stay in the most central point and operate only if fires reached the houses of the area. This fact restricted the potential contribution of a fire crew in the suppression of the fires in the forests and farmland fields (Zirogiannis 2009).

4.2 National and international assistance

The total personnel of the Fire Brigade are about 15,000, 9,500 of which are permanent personnel, dealing also with the structural fires and 5,500 are the seasonally hired personnel just for the forest fires (EFFIS 2007). The Fire Brigade of Greece owns 1,525 fire trucks, which are involved in structural and forest fire suppression efforts. In the summer of 2007 in Peloponnesus, the suppression efforts were also supported by trucks and engines owned by the affected municipalities (considerably small number) and approximately 1,000 soldiers, 200 volunteers of the fire services and hundreds of volunteers and active citizens, while another 402 specified personnel and 32 engines contributed as international aid. In addition, 41 state-owned aircrafts and 16 helicopters were used to assist the operation, while another 19 helicopters and 1 airplane were hired for that purpose (EFFIS 2007; Kapakis 2007). The firefighting fleet of Greece was reinforced by a total of 24 airplanes and 16 helicopters that were offered in the form of assistance by several countries (mainly European). Table 4 summarizes the international aid that assisted the Greek efforts concerning the fire fronts in Peloponnesus.

4.3 Protection measures

In 2003, the Greek government published the "General Plan for Civil Protection" in an effort to form a system that will efficiently deal with extreme natural phenomena and provide the necessary guidelines for civilians in order to ensure their health, safety and property during the occurrence of such events. In more detail, the civil protection plan, entitled "Xenokratis," clearly identifies all participating parties, bodies, authorities and actors that are responsible for managing and coordinating response operations on all levels (national, local). It furthermore grants these entities with crucial data, information and tools so that they can accurately assess and evaluate the impacts of dangerous phenomena, identify endangered areas and develop actions plans for dealing with such events. Finally, it provides the directives for the development of mitigation plans and strategies and the guidelines for the organization and cooperation of the human forces (Isokratis 2003). However, "Xenokratis" did not include any detailed guidelines on specific procedures for managing wild/forest fires (sequence of actions, standard operating procedures, etc.). Although "Xenokratis" clearly assigned the implementation of fire prevention and mitigation measures and the development of specified evacuation and action plans to the local level, prefectures and municipalities did not manage to apply the predeveloped plans during the events of August 2007. In the cases where the action plans were not used, it was either attributed to negligence and panic or to lack of experience on behalf of the responsible actors. For this reason, they now face penalty sentences from the Greek government which purports that when the General Secretariat for Civil Protection ordered the urgent activation of the "Xenokratis" mechanism (a day before the fires reached Ileia's prefecture), the authorities failed to comply (Nodaros 2007a).

4.4 Evacuation orders

The Greek General Secretariat of Civil Protection suggests that civilians living in forested areas should not evacuate their residences unless their evacuation route is guaranteed (General Secretariat of Civil Protection 2007). It is however noteworthy that, after the 2007 wildfires, the responsibility for evacuation was given to mayors, as an effort to maximize the positive outcomes in case of such events. However, the basic strategy during the initial stage of the wildfires was to order the evacuation of settlements in general. Among the initial fires that occurred on August 24, the one started in Artemida village led the locals to evacuate their houses. During the evacuation, two different routes were followed. The evacuees that followed the route leading to the village of Zaharo (located at 1 km distance in the proximity of Artemida) were trapped due to a car accident that blocked the road. As reported by Nodaros, a fire truck heading to Artemida crashed against incoming traffic. That accident blocked the road and trapped the people trying to evacuate. The fire that soon reached the location of the accident burnt 9 people of which 4 were children (Nodaros 2007a, b). This incident was of central importance in the course of the 4-day period, since it formed the way the authorities (the Police and the Fire Department) would react afterward. After this incident, whenever a fire was approaching inhabited locations, the authorities would order the evacuation of the area as soon as possible under the fear of a higher death toll (Zirogiannis 2009). However, according to fire scientists, the authorities should have retained the services of capable villagers who could provide significant assistance to the efforts of fire suppression (Xanthopoulos 2007). Table 5 presents the percentage of settlements in Ileia that were ordered to evacuate. Evacuation orders were

Table 4 International assistance by country (EFFIS 2007)

Country	Date of arrival	Personnel	Fire trucks—engines	Aircrafts	Helicopters
Albania	28/8/2007	4	1		
Austria	27/8/2000			3	2
Bulgaria	31/8/2007	45	5		
Croatia	29/8/2007			1	
Cyprus	26/8/2007	59	6		
Cyprus	27/8/2007	72	8		
France	26/8/2007	64		4	
France	29/8/2007	8			
Germany	28/8/2007			1	3
Hungary	27/8/2007	19	5		
Israel	27/8/2007	60			
Italy	25/8/2007			1	
Netherlands	27/8/2007				3
Norway	28/8/2007				1
Portugal	28/8/2007			1	
Romania	27/8/2007				1
Russia	30/8/2007			1	
Serbia	30/8/2007	55	7	7	
Slovenia	26/8/2007				1
Spain	26/8/2007			4	
Sweden	30/8/2007				1
Switzerland	27/8/2007				1
Turkey	27/8/2007			1	
International volunteers	27/8/2007	7			

given for 89 and 91 % of the villages during days 1 and 2, respectively, while that percentage dropped to approximately 50 % for the following days.

4.5 Volunteer participation

As the event continued, it became evident to the authorities that local residents could significantly contribute to the fire suppression efforts. Given the equipment they had (small agricultural trucks that were transformed to water tanks) and their former experience in dealing with local fires, they proved to be an important firefighting force. Following the Zirogiannis field survey, Table 6 summarizes the day the fire reached the villages of Ileia's prefecture, the existence of evacuation orders and the level of participation in fire suppression by the local residents. Regarding the latter parameter, following factors were taken into consideration for the classification of the "low," "medium" and "high" categories:

- Number of people assisting in the operations
- Age of people assisting in the operations
- Available equipment (farm tractors, water sprinkler mechanisms, etc.)
- Effectiveness of the effort

Table 5 Evacuation orders by day for the villages of Ileia (adapted from Zirogiannis 2009)

Date	Evacuation orders by day	
	No order (%)	Evacuation ordered (%)
24/8	11	89
25/8	9	91
26/8	47	53
27/8	50	50

4.6 Closure of unsafe routes

Shortly after the fires broke out, gradual closures of parts of the road network that were characterized as unsafe were observed. Closures of specific parts of the network occurred either after police orders, based on information about the proximity of the fires to inhabited villages, or due to the fires themselves that affected parts of the road network (Kapakis 2007). Traffic management measures were also applied, in order for people to be able to evacuate, while the authorities ordered the detouring of trips destined to unsafe locations (Michaletos 2007). The temporal character of all measures applied during the 4-day summer period depended on the severity of the event in the respective area.

5 Adaptation measures

5.1 Fire prevention: staff and programs

Wildfire management consists of three stages: prevention, suppression and restoration. Until 1997, the Greek Forest Service has been entirely responsible for wildfire management. However, in 1998, the suppression responsibilities were given to the Fire Brigade, leaving the Greek Forest Service understaffed and poorly funded by Greek authorities, resulting in the rather compromised ability of the Forest Service to effectively carry out fire prevention operations (Georgopoulou 2007). Nevertheless, as of 2008, the Greek state extended the contracts of the seasonal firefighting personnel from 6 to 8 months (April 1 to November 31), in an effort to increase the staff dealing with fire prevention (General Secretariat for Civil Protection 2011). In addition, utilizing the 2007 funding provided by the US Office of Foreign Disaster Assistance, a series of useful fire prevention training programs and technical assistance programs have been made available to Greece. After the 2007 experience, the country's sensibility regarding fire issues increased significantly (Ministry of Public Administrative Reform and e-Government 2011). As a result, the Greek government published a revised version of the "Xenokratis" Civil Protection plan during July 2011 that specifically concentrates on the forest fire issue. Among others revisions, it identifies the Public Electricity Company and the Hellenic Transmission System Operator as responsible actors in wildfire management (General Secretariat for Civil Protection 2011). Furthermore, a lot of municipalities throughout the country currently offer fire prevention and suppression guidelines on their Websites, while as of 2011, no traffic circulation and camping is allowed in national parks, forests and endangered areas in the region of Peloponnesus (Ministry of Public Administrative Reform and

Table 6 Volunteers' participation and evacuation order for the Ileia villages (adapted from Zirogiannis 2009)

Villages	Volunteers' participation	Fire start date	Ordered evacuation	Villages	Volunteers' participation	Fire start date	Ordered evacuation
Agioi Apostoloi	Medium	25/8	x	Miraka	Medium	26/8	x
Agios Georgios	High	26/8		Mouzaki	High	25/8	x
Ambelonas	Medium	25/8	x	Oleni	High	25/8	x
Anilio	Low	24/8	x	Palaiovarvasaina	High	25/8	
Diasella	High	25/8		Parapougi	Medium	25/8	x
Eleonas	Medium	25/8	x	Pelopio	High	26/8	
Fanari	Medium	25/8		Platanos	Medium	26/8	x
Frixa	Medium	27/8	x	Platiana	Medium	25/8	x
Graikas	Medium	25/8	x	Ploutoxori	High	27/8	
Irakleia	High	25/8	x	Pournari	Low	25/8	x
Kafkania	Medium	26/8	x	Skiloudia	High	26/8	
Kalivakia	High	26/8		Smerna	Low	24/8	x
Karatoulas	Medium	25/8	x	Sopi	High	25/8	x
Kladeos	High	26/8	x	Sxinoi	Low	24/8	x
Koliri	Medium	26/8		Tripiti	Medium	25/8	x
Korifi	High	25/8	x	Varvasaina	Medium	26/8	x
Koskinas	Low	26/8		Velanidi	Low	25/8	x
Koutsoxera	High	25/8	x	Vresto	Low	24/8	x
Lambeti	High	26/8		Vroxitsa	Medium	25/8	x
Lanthoi	High	26/8	x	Xaria	High	26/8	x
Lantzoi	Medium	25/8	x	Xeimadio	High	25/8	x
Livadaki	Low	24/8	x	Xelidoni	High	25/8	x
Mageiras	High	26/8	x	Xirohori	Low	24/8	x
Makistos	Low	24/8	x	Zaharo	Medium	24/8	

e-Government 2011). However, as of today (2013), no "Lessons Learned Guidebook" has been published by the state authorities with things to avoid, best practices and recommendations in case of such extreme weather-related events. Finally, evacuation and action plans have been developed by a series of municipalities, which include the allocation of shelter centers that can accommodate civilians during emergency situations, including suggestions of safest possible evacuation routes.

5.2 Forest monitoring and mapping

Forest monitoring and mapping that could prevent and contain wildfires has been at the crux of the agenda of the Greek state since the 2007 fires. Previously, the forest department was under the Ministry of Rural Development and Food. After its move to the new Ministry of Environment, Energy and Climate Change, however, the minister has dealt with the issue of illegal construction in forests, proposing a bill during 2009 that would

Table 7 Recovery plans' budget allocation for the Peloponnese region (AUA 2007)

Actions	Perfectures						Total
	Achaia	Korinthia	Ileia	Arkadia	Lakonia	Messinia	
Environment							
Erosion works	12.34	1.95	45.62	23.73	9.50	8.72	101.86
Protection of water resources	4.35	2.53	30.06	13.27	6.16	6.04	62.41
Restoration and protection of forests	14.7	4.35	23	27	23.2	23	115.25
Production system							
Rehabilitation of damages in oil production	6.06	2.64	81.96	8.14	8.61	9.43	116.84
Rehabilitation of damages in wine production	15.5	3.67	28.90	1.81	0.16	1.55	51.59
Rehabilitation of damages in trees' production	0.19	0.01	1.48	1.2	0.05	0.66	3.59
Rehabilitation of damages in bee production	0.27	0.15	1.41	1	0.53	0.45	3.81
Rehabilitation of damages in animal production	2.33	0.54	60.91	9.2	5.51	7.03	85.52
Processing and services							
Rehabilitation of damages in processing	2.9	0.29	1.68	0.56	0.51	0.44	6.38
Rehabilitation of damages in agrotourism			1.74			0.05	1.79
Infrastructure							
Restoration of road infrastructure surveillance systems/ management of water-related extreme phenomena due to fires	2.34	1.01	29.93	8.21	1.76	1.99	45.24
Stations for forecasting fire events	0.55	0.36	0.45	0.36	0.34	0.46	2.52
Total							
	61.6	17.5	307.1	94.5	56.3	59.8	596.8
Horizontal action 1: direct operational plan for olive productions							0.3
Horizontal action 2: completed program for development of vineyards and restoration of damaged vineyards							0.58
Grand total of program's budget							597.68

postpone any construction on burnt forestland across Greece until specified inspectors establish accurate forest maps.

5.3 Communication, integration and organization

Today, a lack of urgency and senior-level attention still exists, and communication regarding the potential outbreak of large-scale wildfires and how to combat them remains inconsistent. During the fire season of 2007, assistance and funding was provided by several nations. However, Greece was not sufficiently prepared to facilitate or direct such foreign assistance efforts. Integration and coordination between relevant actors is still

considered as inadequate. In addition, efforts to finance early warning systems or elements of Decision Support Systems in Prefectures affected by forest fires led to systems that do not communicate with each other.

5.4 Wildfire management

Following the 2007 fires, USAID's Office of Foreign Disaster Assistance (OFDA) funded a cooperative effort to exchange data, information and details in wildfire management (USAID 2007). The majority of these funds have been used to address immediate needs after the end of the 2007 fires, as well as on technical assistance and infrastructure building in the two subsequent years. More recent efforts have focused on training exercises and included a visit by members of the Greek Forest Service to the USA in 2009.

5.5 Recovery plans

Soon after the fire events in the region of Peloponnesus, the Agricultural University of Athens conducted a detailed rehabilitation and development study for the agricultural sector, the forests and the environmental protection of the regions that were affected. In their study, they conclude that given all respective actions that have to be taken in order for the Peloponnese region to fully overcome the damages and losses of 2007, a total of 597 million euros is needed. Table 7 presents the proposed budget allocation per prefecture, including rehabilitation and restoration of the environmental, production, processing and infrastructure sectors (AUA 2007).

6 Conclusions

The Greek summer of 2007 was the hottest the country had experienced in more than one century. The country was hit by three consecutive heat waves (46 °C) that along with the strong winds and the low relative humidity (9 %) resulted in forest fires breaking out. The region of Peloponnesus in the southern part of the country was mostly affected, especially during the last days of August. The toll of human lives, natural disaster and infrastructure damage was heavy during the time of the event, with its severity peaking between the 24 and 27 of August. During that period, specific measures were taken from all respective actors in an effort to mitigate the impacts of the fires. In general, the authorities were found to be unprepared for an event of such scale, as manifested in the lack of coordination and organization during the first days. As a result, inhabited locations were ordered to evacuate despite what was eventually proven to have been needed. It was often the case that evacuation orders were given to villages independent of whether the area was in danger or not. This significantly reduced the potential contribution of local volunteers in the fire suppression efforts. Although both national and local plans were developed beforehand in case of extreme weather emergencies, they were only partially followed. Consequently, the well-being of evacuees was seriously endangered, since the latter would choose routes that were later proven to be unsafe. Furthermore, people who could have assisted in facing the increasing fire fronts throughout the event's propagation were left unused and thus deprived the fire fighters of an additional force. This point gains significantly in importance and criticality taking into consideration that the volunteer participation proved to be decisive in the suppression of the fires.

This paper has presented a detailed overview of the 2007 wildfires in Peloponnesus, both in terms of the event's temporal and spatial propagation, description and impacts on various sectors, as well as the emergency management and adaptation measures that followed.

There seems to be room for potential improvement in all respective aspects of wildfire management (prevention, suppression, restoration). With regard to the aspect of fire prevention, a series of measures have already been taken in terms of educational programs and technical assistance of the firefighting crew from international parties. In addition, the national and local civil protection plans have been revised and updated since the events, as their severity motivated both the authorities and the public. More specifically, evacuation and action plans have been developed that explicitly include the allocation of shelter zones and centers that can accommodate civilians during emergency situations. Furthermore, they deal with the designation of the safest possible evacuation routes in order to ensure evacuees' secure distribution to the predefined areas.

The fire events of summer 2007 in Greece highlighted the lack of cost estimation tools for assessing the impacts of such extreme phenomena; such tools could identify which adaptation measures are needed for each specific case and assess their respective cost. Finally, with climate change being as prevalent as ever, similar events are inevitably to be observed in the future. A risk analysis study at a national level for vulnerable and sensitive areas is therefore necessary, in order to define the measures that have to be taken prior to the occurrence of adverse events and allocate the respective budget.

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