Ecological and climatic drivers for the fire regime in the Mediterranean under climatic change

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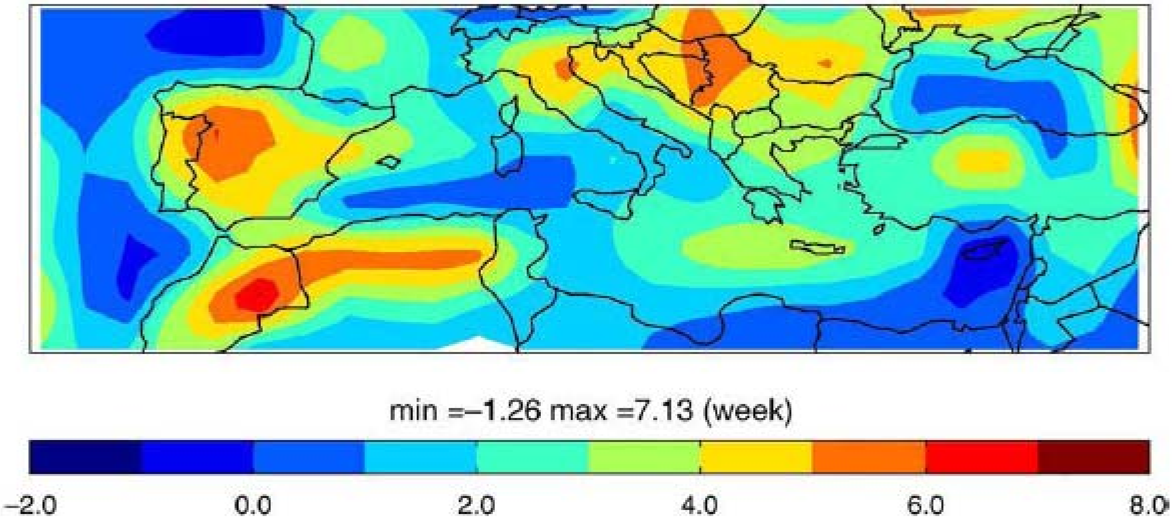
❑ INTRODUCTION

* Under climatic change, warmer and drier conditions are expected to increase the pressure from wildfires in the Mediterranean (Westerling and Bryant, 2008; Giannakopoulos *et al.* 2009; Dury *et al.* 2011).



Changes in the number of weeks with fire risk (FWI>15) between 1961–1990 and 2031–2060 when a 2 °C global warming is most likely to occur (Giannakopoulos *et al*. 2009)

* Therefore, more research is needed to better understand, predict and combat wildfires.

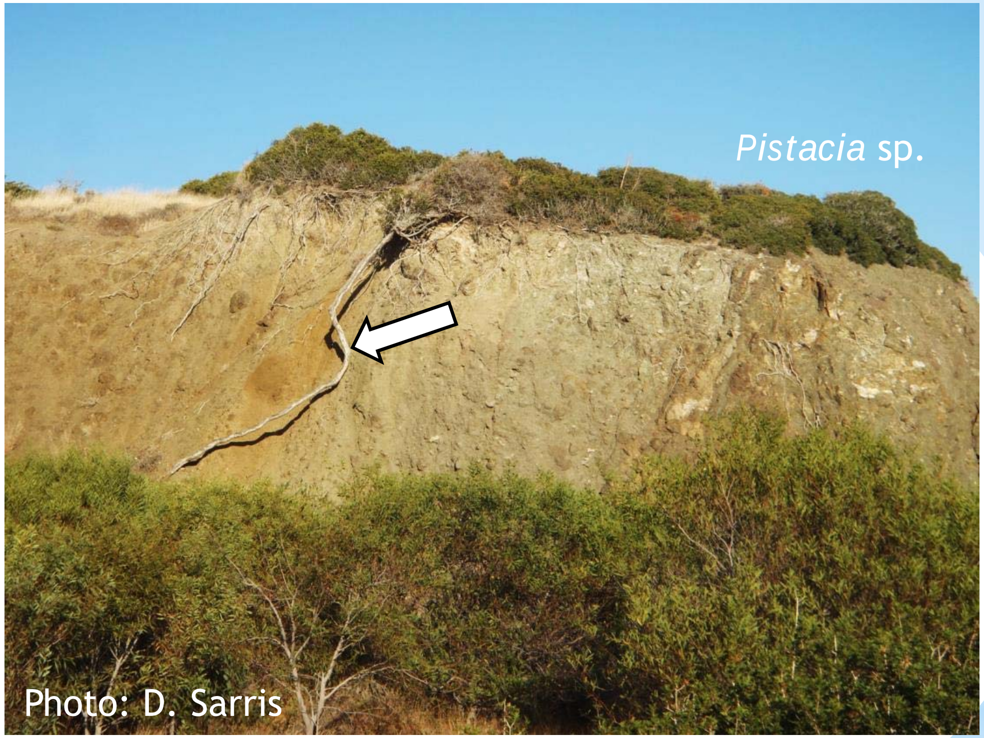
❑ INTRODUCTION

* We often forget that in north Mediterranean forests, burning fuel consists mostly of living fuel, especially during severe (crown) fires.

Figures. Typical conifer forests (mostly pines), olive tree groves and macchia (sclerophylous evergreen shrubs) at low altitudes in the Mediterranean [thermo- and meso (medio-) Mediterranean vegetation belts (TMVB-MMVB)]

❑ PROPERTIES OF TMVB-MMVB LIVING FUEL

* *Living fuel* at low altitudes is composed of **deep-rooted plants** (phreatophytes)



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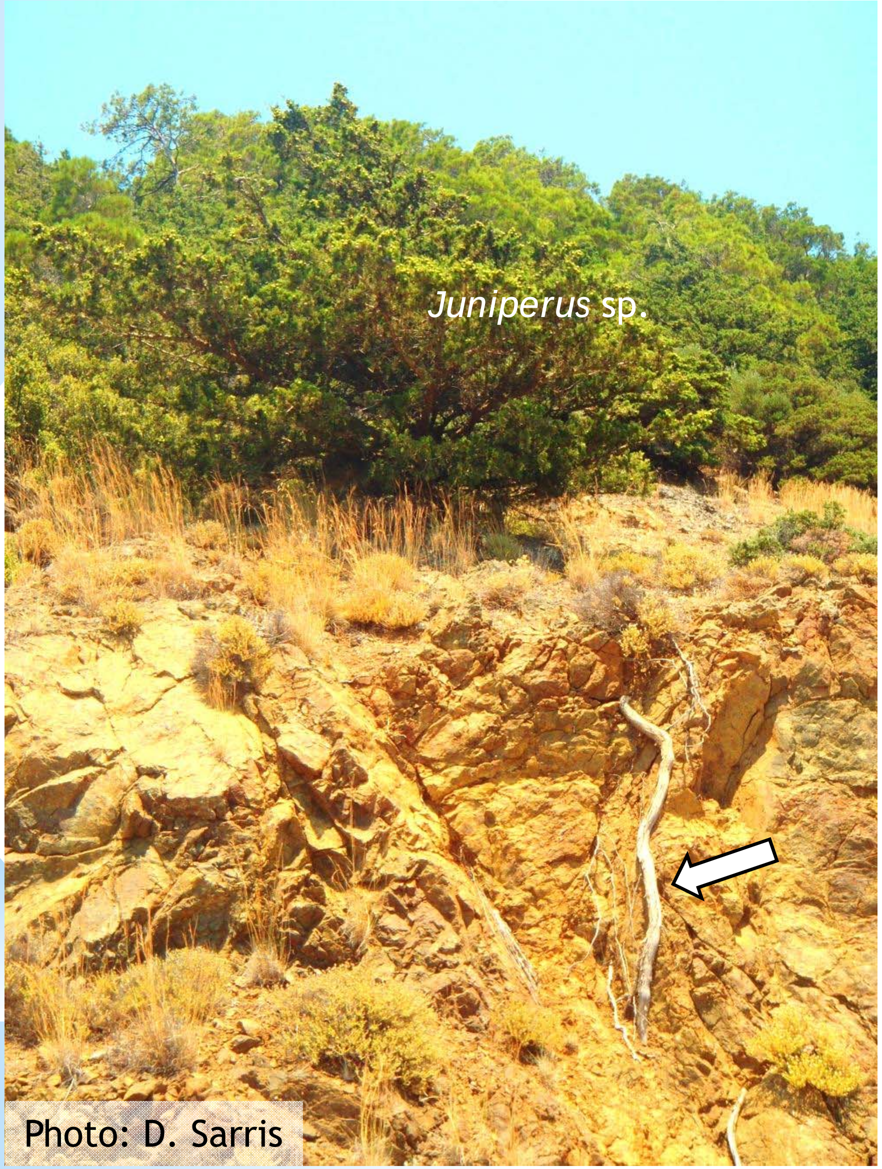
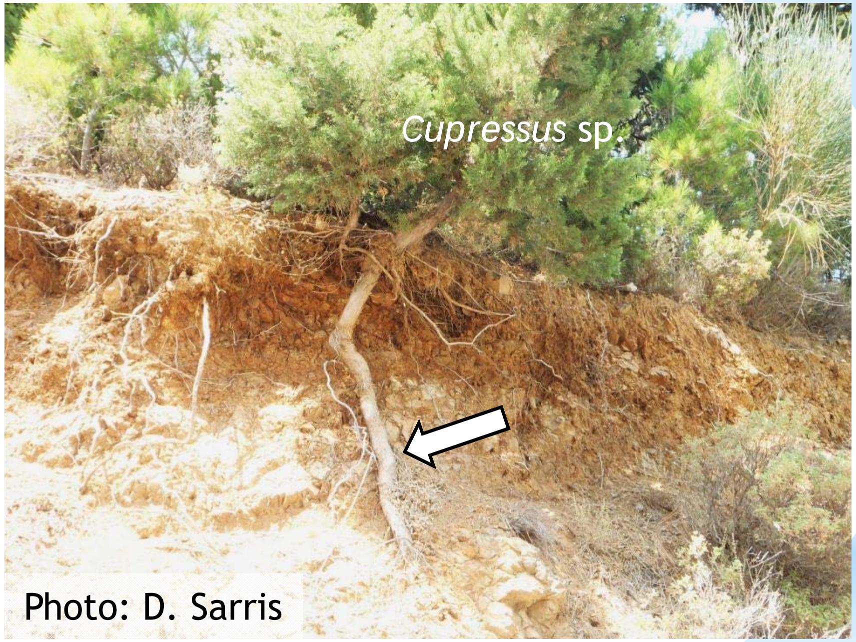
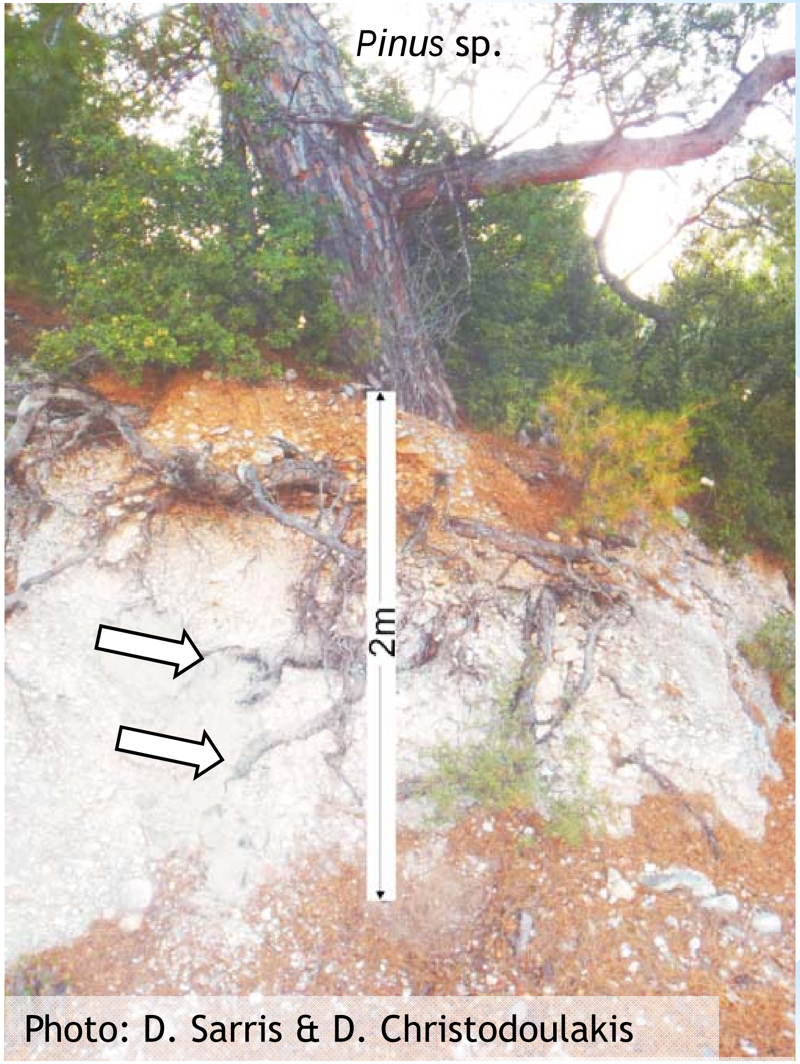




❑ PROPERTIES OF TMVB-MMVB LIVING FUEL

* Such **deep-rooted plants** (phreatophytes) survive the Mediterranean dry season by utilizing moisture accumulating belowground from past rainfall events (*see Sarris et al. 2013 for more details*).

* This also influences the *moisture content of phreatophytes in summer* when acting as *living fuel* for forest fires.



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❑ WHY IS MOISTURE CONTENT IN VEGETATION VERY IMPORTANT FOR FIRE BEHAVIOR ?

1. **High** *moisture content* in vegetation *increases the heat required* to ignite a fuel, since some of this energy is used to evaporate water.

2. *More energy is consumed* to evaporate water from burning vegetation, leaving less energy available for a fire to propagate.

3. Since the air will have more water vapor, *less oxygen will be available* for combustion.

The role of *moisture content* in vegetation is critical for converting a surface fire into a crown fire.

❑ PROPERTIES OF *DEAD* FINE FUEL IN TMVB-MMVB

* Shallow-rooted herbaceous plants (therophytes) survive drought as seeds, acting as very flammable fine fuel because their biomass totally desiccates in summer.
* The size of this therophytic biomass depends on available rainfall during their growing season (spring for CS Greece).

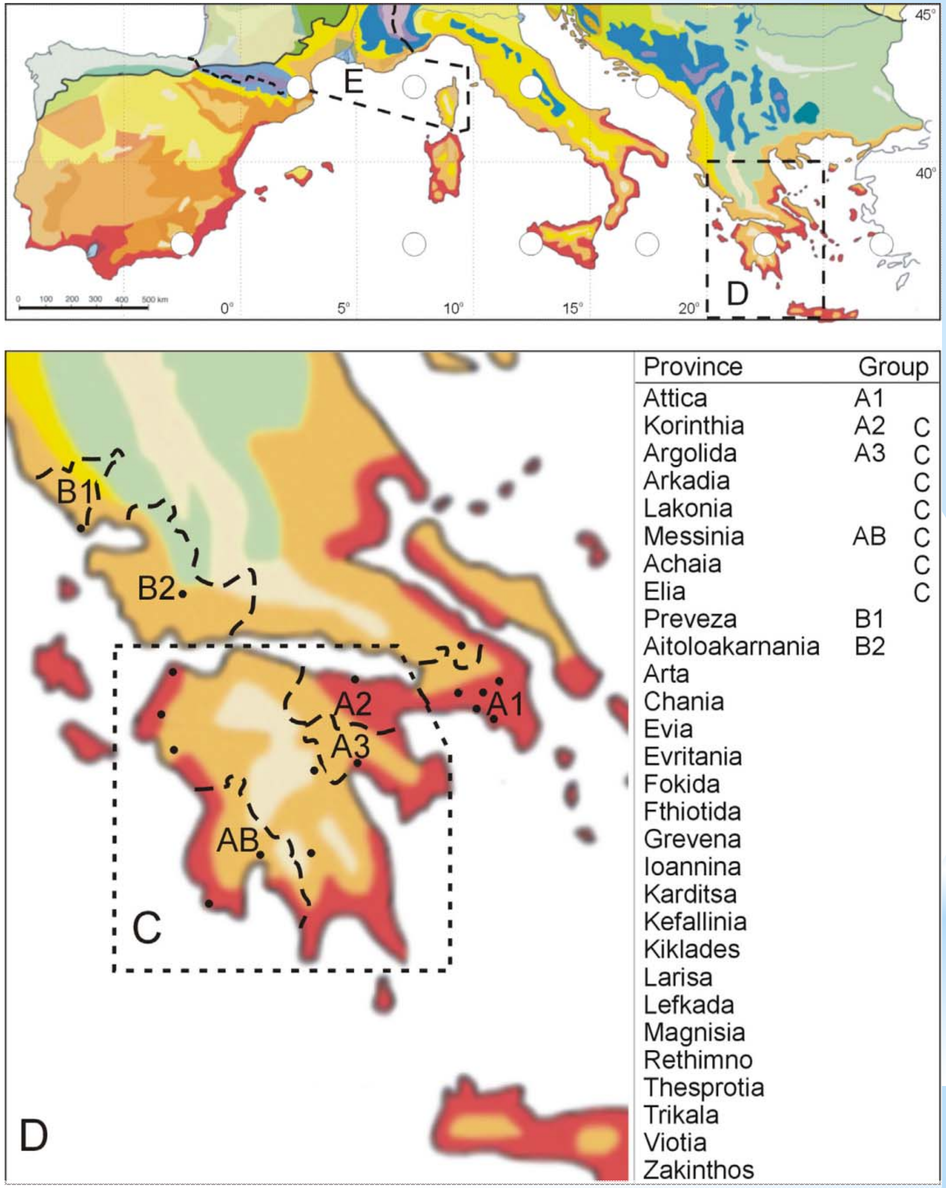
Photo: D. Sarris

❑ OUR AIM…

* Investigate the effects that these functional and structural ecological adaptations of plants to drought may have in shaping the fire regime in the TMVB-MMVB (the most arid and flammable regions).

<u>*Used statistics for:*</u>

* **Burnt area (BA)**
* Number of fires (NF)
* Applied correlations between fire statistics and climate (*P* and *T max*) for 1985–2008 (and its sub periods); one of the driest periods for the Mediterranean, with large-scale fire occurrence.

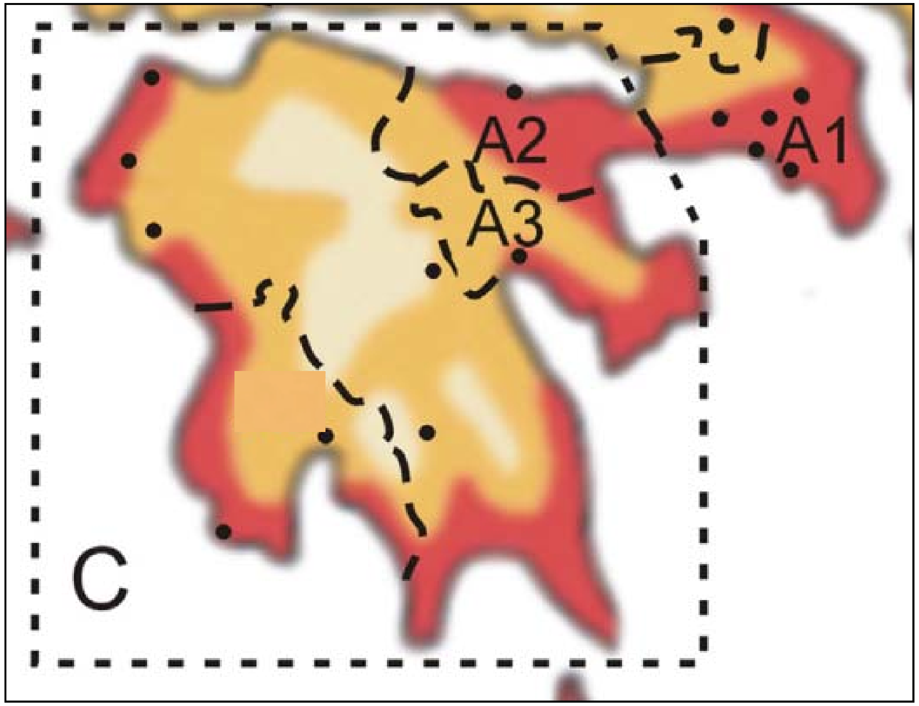


Province	Group	
Attica	A1	
Korinthia	A2	C
Argolida	A3	C
Arkadia		C
Lakonia		C
Messinia	AB	C
Achaia		C
Elia		C
Preveza	B1	
Aitoloakarnania	B2	
Arta		
Chania		
Evia		
Evritania		
Fokida		
Fthiotida		
Grevena		
Ioannina		
Karditsa		
Kefallinia		
Kiklades		
Larisa		
Lefkada		
Magnisia		
Rethimno		
Thesprotia		
Trikala		
Viotia		
Zakinthos		

(Sarris and Koutsias 2014; Ozenda and Borel, 2000; modified).

RESULTS

- Burnt area (BA) vs. Precipitation (*P*) correlations for the **driest** provinces: A1, A2-A3, C



Southern Greece

Table 2
Coefficients r (Spearman's) from running correlations between integration periods of P and BA for Groups A and C. Correlation's stability (sb; see 1.4) is provided only when it is above 20%. Positive correlations in gray shading.

Group	First year of correlation	Oct–Sep	Nov–Aug	Nov–Mar	Dec–Feb	Mar–May	Apr–May	May	Jun–Sep
A1	1985	*	*						*
	1986	*	**	*	*				
	1987	*	*	*	*				
	1988	*	*	*	*				
	1989	**	**	**	*				
	1990	*	*	**					
	1991	*	*	*					
	1992	*	*	*					
	1993	*	*	*					
	1994		*						
	1995		*	*					
	1996		*	*					
	1997		*	*					
	1998								
	1999								
	2000		**	**					
	2001		*	*					
	2002		*	*					
	sb (%)	50	89	78	22				–
A2–A3	1985	****	**	**	*			*	*
	1986	***	**	**	*			*	*
	1987	***	**	**	*			*	*
	1988	**	**	**	*				
	1989	**	**	**	*				
	1990	**	*	*	*				
	1991	**	*	*					
	1992	*	*	*				*	
	1993	*						*	
	1994					*			
	1995					*			
	1996								
	1997	*	*	*		*			
	1998								
	1999								
	2000		*	*		*			
	2001							*	
	2002							*	
	sb (%)	56	61	56	33	–		39	–
C	1985								
	1986								
	1987								
	1988				*				
	1989	*	*	*	*				
	1990	*	*		*				
	1991	*	*		*				
	1992	*							
	1993								
	1994								
	1995								
	1996								
	1997								
	1998								
	1999								
	2000								
	2001								
	2002								
	sb (%)	22	–	–	22				

2008, last year of correlation.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.
**** $P < 0.0001$.

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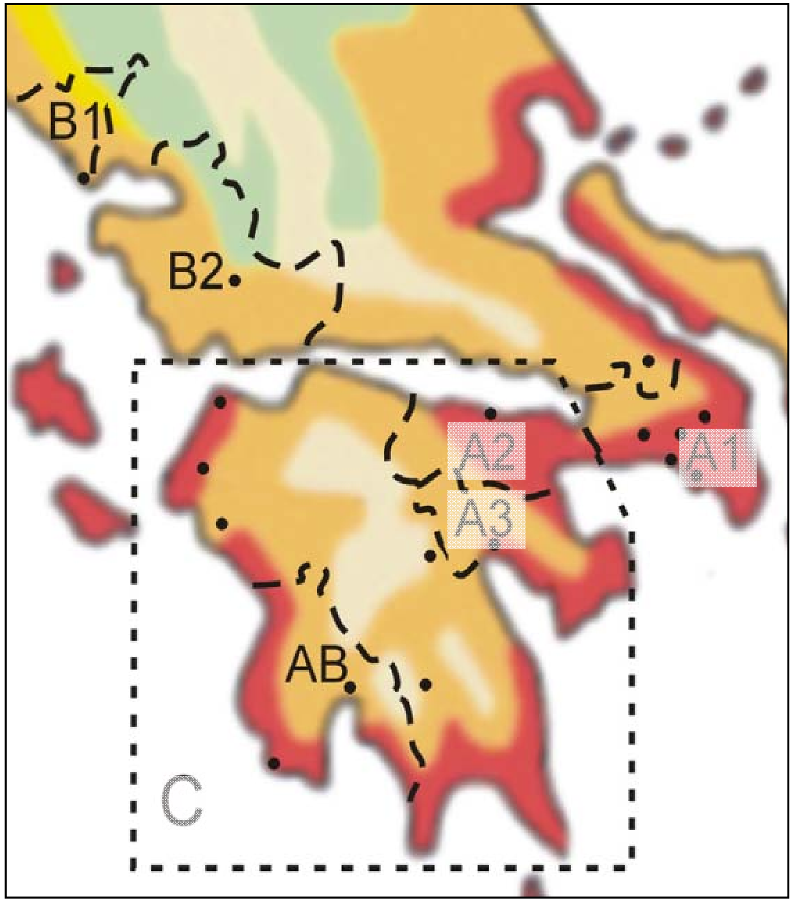
❑ RESULTS

- Burnt area (BA) vs. Precipitation (*P*) correlations for the **wettest** provinces: AB, B1-B2



Central & Southern Greece

Table 3

Coefficients *r* (Spearman's) from running correlations between integration periods of *P* and BA for Groups AB and B. Correlation's stability (*sb*; see 1.4) is provided only when it is above 20%. Positive correlations in gray shading.

Group	First year of correlation	Oct–Sep	Nov–Aug	Nov–Mar	Dec–Feb	Mar–May	Apr–May	May	Jun–Sep
AB	1985								*
	1986								**
	1987								**
	1988								**
	1989	**	*					*	**
	1990	**	*					*	**
	1991	**	*	*				*	***
	1992	***	**	*				*	**
	1993	**	*					*	**
	1994	**							**
	1995	**	*						**
	1996	*	*					*	***
	1997	*						*	**
	1998								
	1999								
	2000	*						**	**
	2001							*	*
	2002							**	**
	sb (%)	56	39	–				56	89
B1–B2	1985	*							***
	1986	*							**
	1987	*							**
	1988	*							**
	1989	**							*
	1990	**							*
	1991	*							*
	1992	**							*
	1993	*							*
	1994								*
	1995	*							
	1996								
	1997	*							
	1998								
	1999								
	2000								
	2001								
	2002								
	sb (%)	61							56

2008, last year of correlation.

* $P < 0.05$.

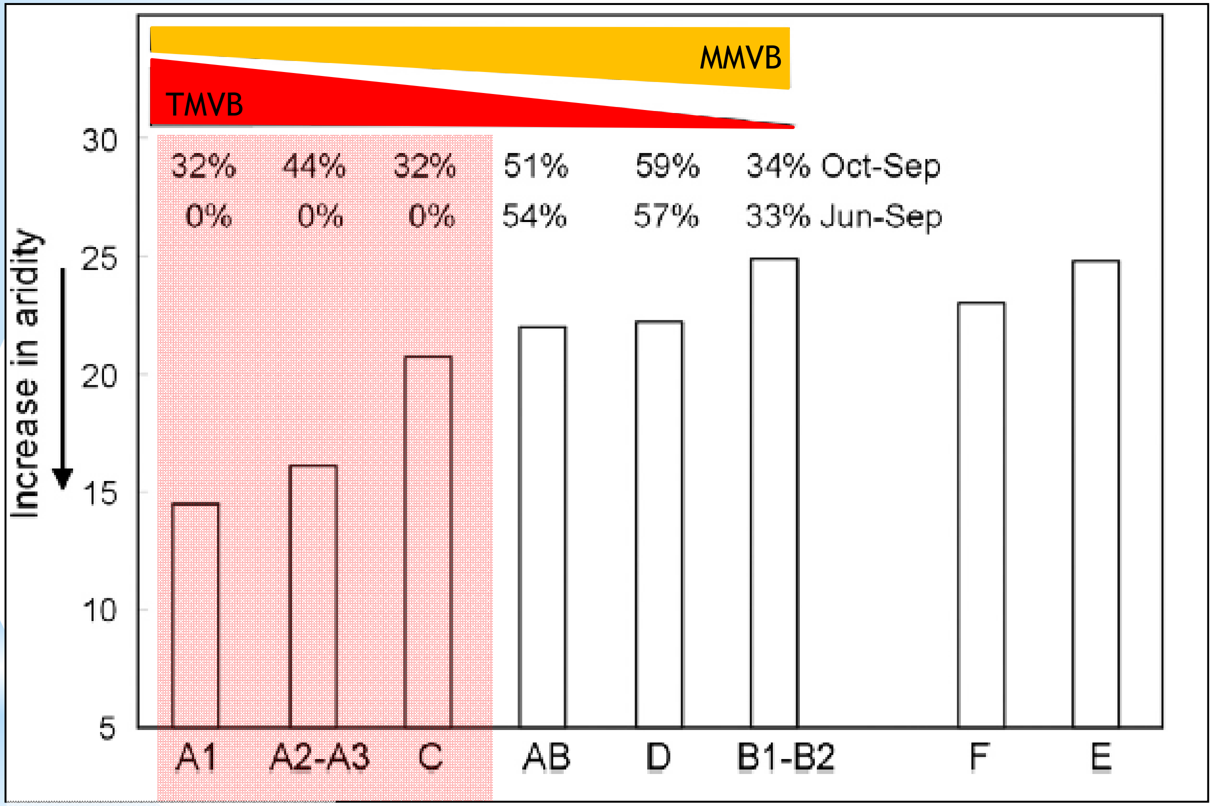
** $P < 0.01$.

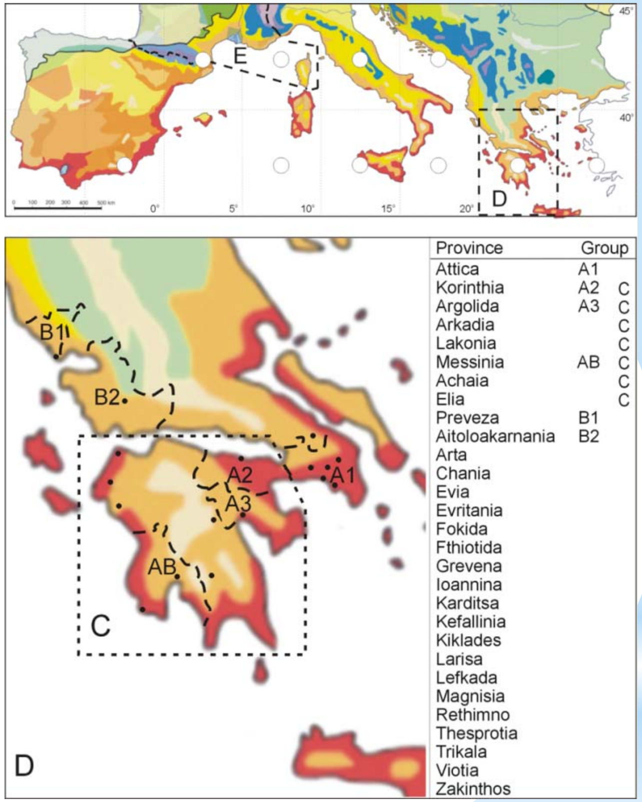
*** $P < 0.001$.

**** $P < 0.0001$.

❑ RESULTS

- Only annual (mostly winter) *P* has a significant effect on fire spread in the driest regions!





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❑ CLIMATE AND LARGE FIRE OCCURRENCE AT HIGH ALTITUDES

- At higher altitudes, **aridity and fuel availability** are both expected to increase fire danger, because of **climatic and land use changes** in mountains of the northern Mediterranean basin.
- There may already be signs of such effects in the case of the *Pinus nigra* and *Abies cephalonica* forests on Mt. Taygetos (S. Greece).

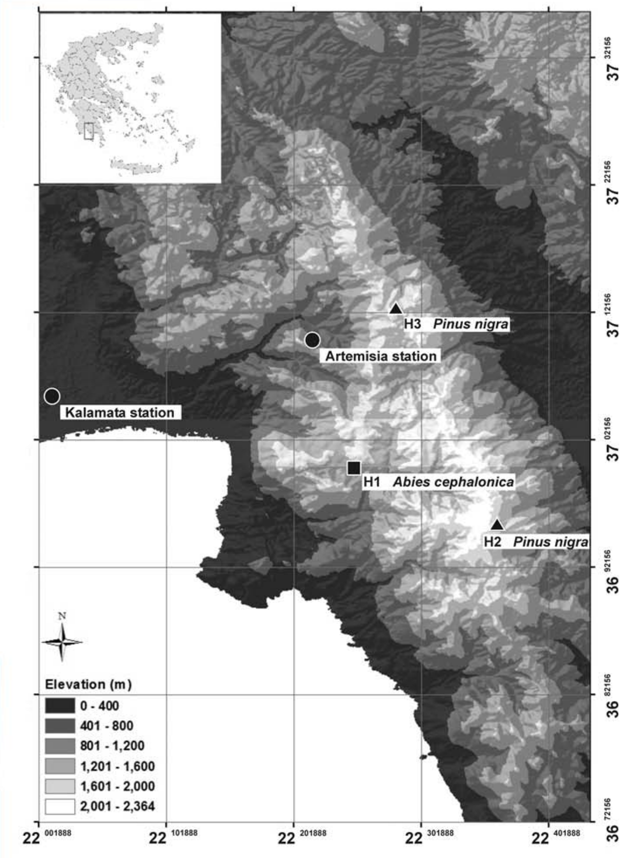
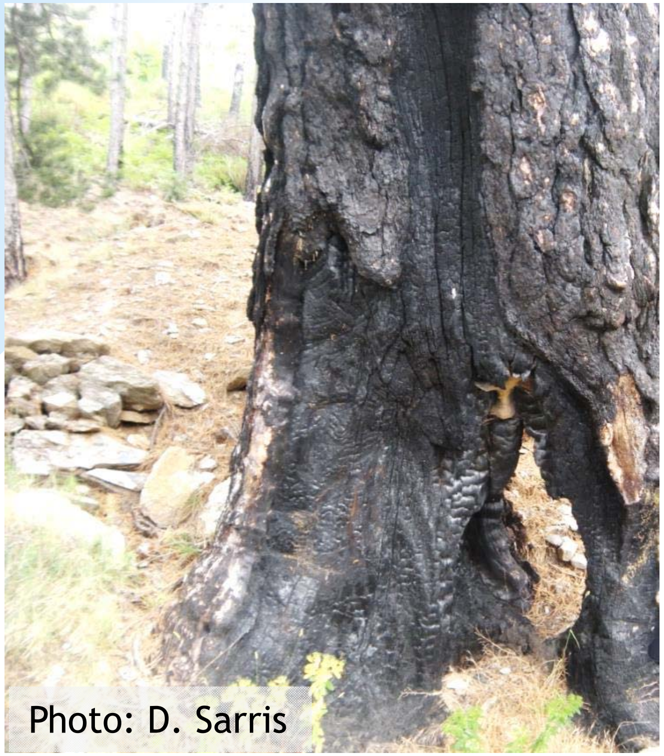


Photo: D. Sarris

❑ CLIMATE AND LARGE FIRE OCCURRENCE AT HIGH ALTITUDES

* Reconstructed the mountain's fire history from *Pinus nigra* fire-scars (Christopoulou *et al.* 2013)



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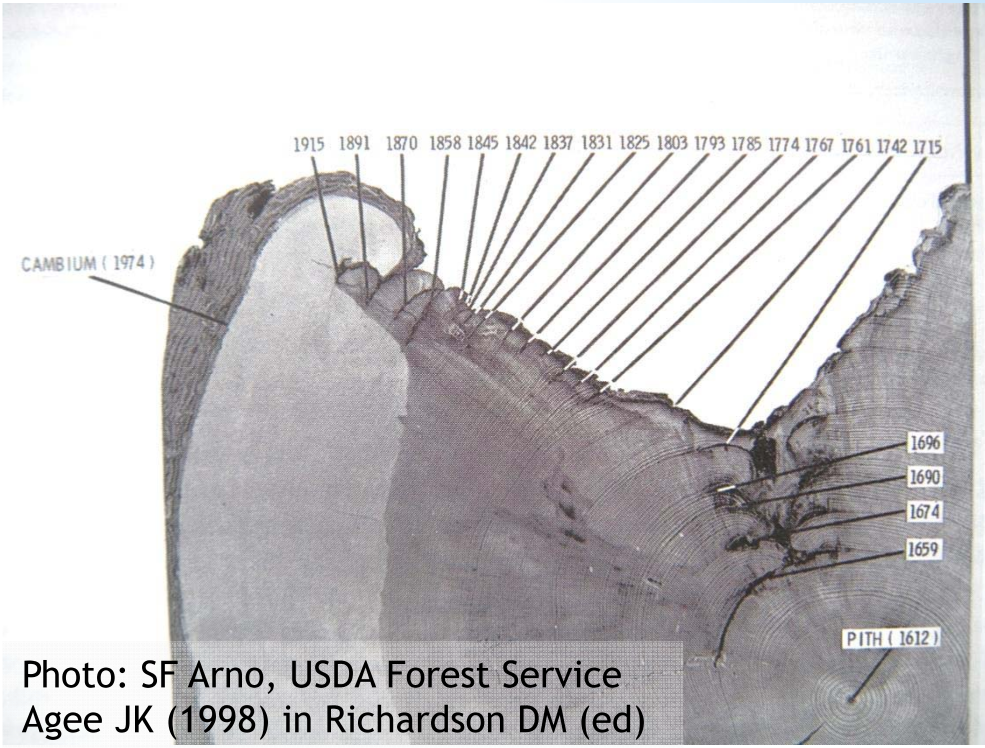
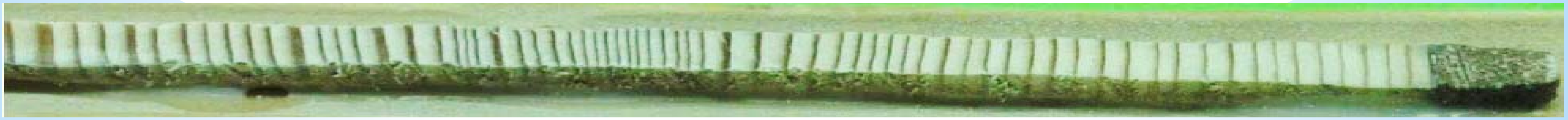
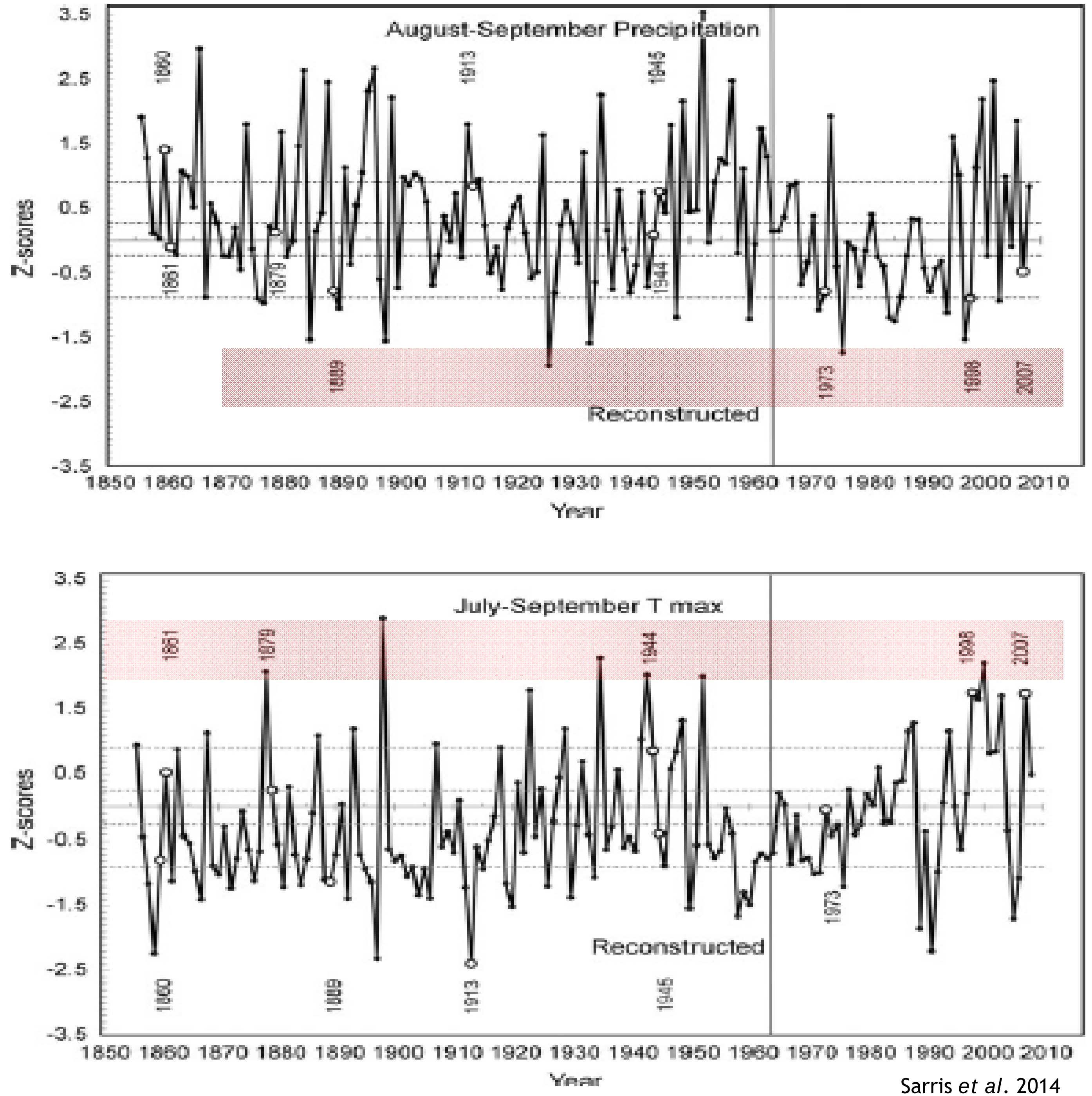


Photo: SF Arno, USDA Forest Service
Agee JK (1998) in Richardson DM (ed)

* Reconstructed climate (mid to late-fire-season drought) for the mountain using *Pinus nigra* and *Abies cephalonica* tree-rings for the last 150 years (Sarris *et al.* 2014)





Sarris *et al*. 2014

The dates refer to the 10 most extensive fires on Mt. Taygetos

❑ CLIMATE AND LARGE FIRE OCCURRENCE AT HIGH ALTITUDES

* Seven, out of the ten, large fires Mt. Taygetos experienced, were associated with below normal *P* or above normal *T max*. **The largest fires occurred in late summer of 1879, 1944, 1998 and 2007.**
* However, only the recent fires (1998 and 2007) had both low *P* and high *T max*, also confirmed from long-term meteorological data.

Table 1 Fire years coinciding with below-average precipitation ($z < -0.25$) or above-average T_{max} ($z > 0.25$)

Fire year	Prec. August–September	T_{max} July–September
1860		
1861		+
1879		+
1889	+	
1913		
1944		+
1945		
1973	+	
1998	+	+
2007	+	+

Note that for 1998 and 2007 both cases occur

Sarris *et al.* 2014

❑ BUT WHAT HAPPENS IF FUEL AVAILABILITY ALSO INCREASES ?

* The **synergy** between climate and fuel availability can explain the **very high intensity of 1998 and 2007 fires** that burned mostly as **stand-replacing crown fires** on Mt. Taygetos (Sarris *et al*. 2014).

Pinus nigra stands on Mt. Taygetos after the 2007 fire

Photo: D. Sarris

❑ KEY MESSAGES…

27 – 28 March, 2014 International Conference ADAPTtoCLIMATE Filoxenia Conference Centre Nicosia, Cyprus

- The recent and distant past supports the prediction, that northern Mediterranean areas will face a very large threat from fires in the 21st Century, at both lower and higher altitudes.
- Especially, if social and economic changes leading to *desertion of land* and thus *accumulation of burning fuel* are combined with the *drought intensification* projected for the region under global warming.

But also… some optimistic findings

- During the summer fire season **autumn-winter** *P* was found to determine fire spread in the driest forested areas, as it regulates *moisture content* in pheatophytic vegetation (*living fuel*).
- Thus, the potential exists **to expand early fire-danger prognosis** by incorporating autumn to late winter *P* (prior to the fire season) into fire forecasting models.

❑ FORE MORE DETAILS…

Sarris D, Koutsias N. (2014) Ecological adaptations of plants to drought influencing the recent fire regime in the Mediterranean. *Agricultural and Forest Meteorology*, 184, 158–169.

Sarris D, Christopoulou A, Angelonidi E, Koutsias N, Fulé PZ, Arianoutsou M. (2014) Increasing extremes of heat and drought associated with recent severe wildfires in southern Greece. *Regional Environmental Change*. (published online) DOI 10.1007/s10113-013-0568-6

Christopoulou A, Fulé P.Z, Andriopoulos P, Sarris D, Arianoutsou M. (2013) Dendrochronology-based fire history of *Pinus nigra* forests in Mt Taygetos, Southern Greece. *Forest Ecology and Management*, 293, 132-139.

Thank you very much for your attention !

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