Final report of the Short Term Scientific Mission COST ACTION FP1204

Wildfires in urban and peri-urban forests in Israel and associated weather conditions

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1 Introduction

Forest fires are a serious environmental hazard in Mediterranean regions with severe economic and environmental damage and life loss. Over the last decades, changes in climate and other environmental and socioeconomic factors have significantly affected fire regimes [Saaroni et al. 2014; Turco et al. 2014; Ziv et al. 2014]. The highest fire risk areas are at the interfaces between urban and wildland, that is, at the Wildland Urban Interface (WUI). As a consequence of climate change, climate extremity and the WUI extension, there is a growing awareness of the fire risks. This is especially important for regions located at the border between climatic regions such as Israel, where urban and peri-urban forests are planted in both Mediterranean and semi-arid climates.

Taking into account these considerations, during this STSM we have planned to assess the fire risk in Israel, focusing on urban and peril-urban areas, in order to support end-users in developing adequate measures of prevention and adaptation. During this STSM we have started to collect and analyse the latest publicly available databases of fires, land cover variables and relevant weather/synoptic database and I had three field travels of urban and peri-urban forests surrounding the Haifa metropolitan area (The Carmel forest), Tel Aviv metropolitan area, and surrounding Jerusalem (Mevo Beitar forest). Apart from some promising results achieved, the STSM served to establish useful collaborative relations with the host group. After completing the data examination, it is planned to prepare a paper with the main output.

Specifically to long-term objective of the analysis that follows this STSM, is the assessment of fire risk in the WUI and a better understanding of the climate and weather conditions associated with large fires in Israel forests in general and in urban and peri-urban forests in particular. The relevance for GreenInUrbs relies on the expected scientific results that fit the objective of working group WG1:

"Environmental services of green infrastructure and urban forests, and implications of climate change". During and after the STSM we have focused on the analysis on recent changes in drought and forest fires. In the following a summary of this work is reported.

2 Methods

2.1 Study area

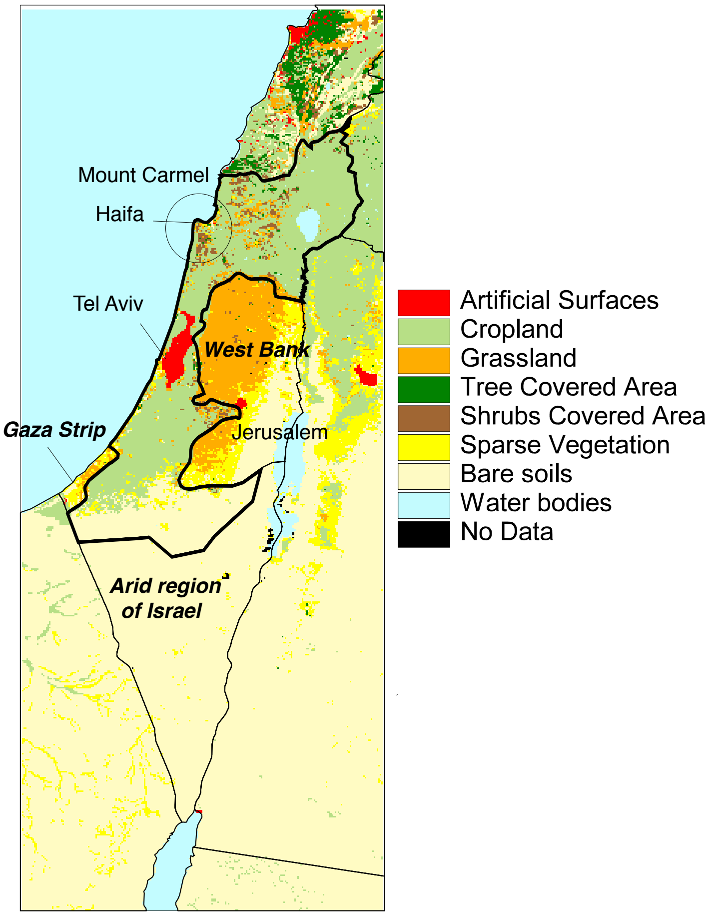

Figure 1. Domain of study and dominant land cover from the Global Land Cover data set GLC-Share [Latham et al., 2014]. We focus on the Mediterranean and semi-arid region of Israel, indicated by the black thicker line. The circle denoted the region of Mount Carmel, surrounding the Haifa metropolitan area, where the largest fire occurred in 2010. This fire is chosen for further case study analysis.

Israel is positioned at the intersection of three continents and has high climatic and land cover diversity (see Figure 1). The arid region of Israel, in the south, receives less than 200 mm of rain in a year and the dominant land cover type is bare soils. The northern half receives annual precipitation levels of 400 to 900 mm and both native and mostly planted forest exist and cover around 7% of

Israel's total area. Also located in this area are all of Israel's major metropolitan centres: Haifa (close to the Mount Carmel), Jerusalem and Tel Aviv. The semi-arid region, having annual precipitation of 200-400mm, has also large planted forest.

2.2 Data

We consider drought information based on different data sets and on three different drought indicators: the Standard Precipitation and Evaporation index (SPEI; Vicente-Serrano et al. [2010]), the Standardized Precipitation Index (SPI; Mc-Kee et al. [1993]) and the Standardized Soil moisture Index (SSI; Hao et al. [2014]). SPI has been widely used as an indicator of meteorological drought and is recommended by the World Meteorological Organization [WMO, 2012]. SPI transforms the accumulated precipitation values over a specific period (usually from 1 to 12 months) into a Gaussian distribution with mean zero and standard deviation of unity. Positive values indicate conditions of above-normal precipitation, while negative values identify dry situations. The SPEI indicator is mathematically similar to SPI, but includes also the effects of temperature, that expressed the potential evaporation [Vicente- Serrano et al., 2010]. Also the SSI indicator is analogue to SPI (mathematically) and could be considered a proxy for agricultural drought, since it is based on anomalies in soil moisture.

SPI and SSI are calculated using a nonparametric approach as described in details in Hao et al. [2014]. In this method the probabilities of precipitation and soil moisture are calculated empirically and not by fitting a parametric distribution function. The probability distribution of precipitation and soil moisture are computed using the empirical plotting Gringorten rule [Gringorten, 1963]. We calculate SPI from the publicly available precipitation gridded data set E-OBS (v11.0, 25 km 25 km; Haylock et al. [2008]) over the period 1950-2014. SSI data sets are publicly available at http://drought.eng.uci.edu/ and are based on the monthly soil moisture from the NASA Modern-Era Retrospective analysis for Research and Applications (MERRA-Land), available on a 2/3° × 1/2° grid from January 1980 to December 2014. MERRA data set is considered substantially reliable since it is consistent with observations [Reichle et al., 2011]. Finally, SPEI is based on monthly precipitation and potential evapotranspiration from the Climatic Research Unit of the University of East Anglia (CRU version 3.22). SPEI data and additional information on this indicator are available at http://sac.csic.es/spei/database.html.

Data of fire occurrence and burned area are obtained from the Jewish National Fund, "Ha Keren ha Kayemet le Yisrael" (JNF), responsible for most Israeli forests. This data cover the period 1987–2011. We focus on two standard fire variables: the total burned area (hereafter, BA) and the total number of fires (NF). In calculating these variables, we consider only fires larger than 0.1 ha in order to reduce potential inhomogeneity in fire detection. It must be noted that these data present some limitations since differences in fire data documentation in Israel results from organizational changes and from different managing authorities involved in nature conservation (JNF, Israel Nature and Parks Authority (INPA) and the Fire Department), each with a different basis and modus vivendi. Unfortunately, parts of the data are missing, and documentation is incomplete. However the available data provide some basic information on fire regimes in Israel, at least considering the data aggregated over the entire country and over different months and years.

2.3 Statistical measures

We use the Theil-Sen estimator to assess long-term trends [Sen, 1968]. This method defines the trend as the median slope among all possible lines through pairs of points. With respect to classical least-squares estimators, this method is less sensitive to outliers and it is applicable also for non-normal data distribution. The trend significance is estimated using the Bootstrap test implemented by Turco and Llasat [2011]. For more details on this method, the readers are referred to Kiktev et al. [2003] and Turco and Llasat [2011]. The practical implementation is briefly summarized here. This method firstly decomposes the fire series into a linear trend line and a time series of residuals, then the residuals are resampled 1000 times and added back to the best fit line obtaining 1000 new plausible trend estimations, and finally, the original trend significance is estimated considering if the zero-trend falls outside the distribution of these 1000 plausible trend values. The code to implement this method is publicly available at the web-site http://www.am.ub.es/~mturco/codes/testTrend_MT.zip. We obtained similar results applying the standard Mann-Kendall trend test.

The correlations are calculated by the Spearman rank correlation coefficient, being more robust to outliers than the classical Pearson correlation. We estimate the significance of the correlation coefficients by employing a bootstrap technique in which one of the time series is kept fixed while the other is randomly shuffled before estimating the correlation coefficient. The procedure is repeated 1000 times and the empirical probability that the estimated value of the correlation coefficient do not occur by chance is represented by the fraction of random-coefficients that are lower (in absolute value) than that obtained from the original (unshuffled) time series.

3 Preliminary Results

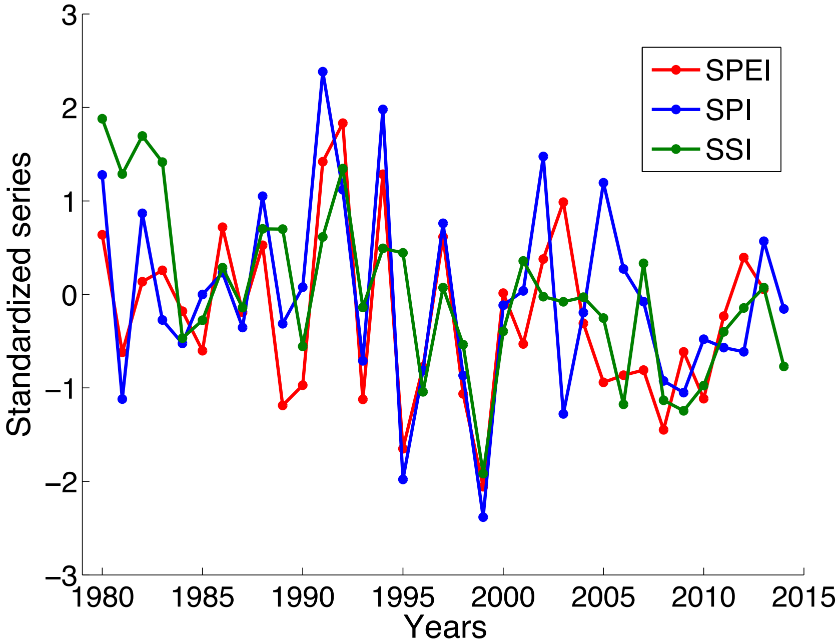

Figure 2. Drought indicators SPEI, SPI and SSI averaged over the Mediterranean and semi-arid climatic regions of Israel. The indicators refer to the accumulation time of 12 months, between 1980 and 2014.

Figure 2 shows the evolution of the three drought indicators considered. The indicators show similar interannual fluctuation overlying a common negative trend. Since negative values of these indices indicate dry conditions, this means that drought conditions in Israel are increasing. This trend is statistically significant (see Table 1) being the most evident in spring.

Index	ANNUAL	DJF	MAM	JJA	SON
SPEI	-0.2*	-0.1	-0.4***	-	-0.1
SPI	-0.2*	-0.1*	-0.4***	-	0.1
SSI	-0.5***	-0.3**	-0.5***	-0.4***	0.0

Table 1: Trends for drought indicators for the period 1980-2014 (except SPEI, available for the period 1980-2013). Trend units are standardized unit per decade−1. *p<0.10,**p<0.05,***p<0.01. The seasons are: DJF (December-January-February), MAM (March-April-May), JJA (June-July-August) and SON (September-October-November). For JJA season SPEI3 and SPI3 are not calculated since rain events are rare in these months (Saaroni and Ziv 2000).

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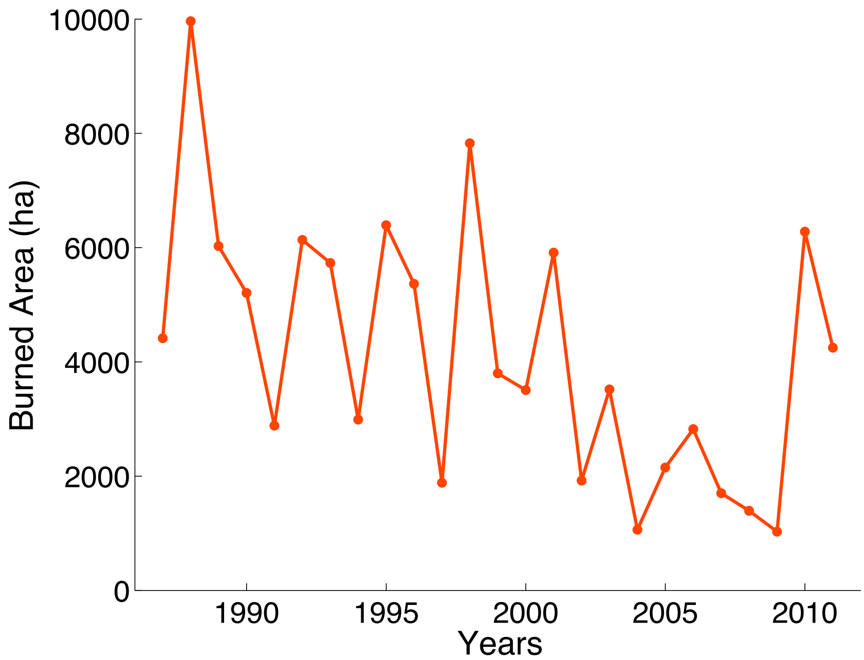

Figure 3. Total Burned Area evolution in Israel from 1987 to 2011.

The total area burned by forest fires (Figure 3) has large variability, probably reflecting a dependence on seasonal fuel and climatic conditions. The high value for 2010 stems mostly from the largest fire at Mount Carmel on December 2010 (to be further studied). Nevertheless, and together with the drying and warming conditions in Israel (Ziv et al., 2014), a negative trend is apparent. Similar evolution occurs also considering the Number of Fires (not shown). An increasing effort in fire management could be a reason for this evolution. To assess the negative annual trend presented, we have estimated the trends of the BA and NF series also on a seasonal scale, (see Table 2). Both the BA and NF series display a significant decreasing trend over most parts of the year.

Variable	ANNUAL	DJF	MAM	JJA	SON
BA	-1750***	-	-250*	-821***	-297***
NF	-138**	-	-20	-64***	-47**

Table 2: Trends for Burned Area (BA; ha/decade) and for Number of fires (NF; number/decade) for the period 1987-2011. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Very few fire events occur in the winter (DJF) season, thus this season is excluded from the trend analysis.

Next, we calculate the correlation between drought (using the 3 indices) and fire (BA and NF). All the correlations consider linear detrended series, in order to reduce the effect of confounding factor acting at scale longer than the interannual scale (see e.g. Turco et al. [2014]). We calculate the drought indicators considering different accumulation time τ: 3, 6 and 12 months, where τ = 3, 6 or 12 corresponds to a drought anomaly over 3, 6 or 12 months and relative to the past τ months before the end of the season or of the year. For instance, $SPEI_3$ in MAM indicates the drought conditions over the 3 months on the spring (MAM) season. The results are shown in the following tables (Tables 3 and 4).

	ANNUAL	DJF	MAM	JJA	SON
$SPEI_3$ vs. BA	–	–	-0.08	–	-0.30
$SPEI_6$ vs. BA	–	–	0.11	0.15	-0.30
$SPEI_{12}$ vs. BA	-0.29	–	0.05	0.42**	0.08
SPI_3 vs. BA	–	–	-0.19	–	-0.30
SPI_6 vs. BA	–	–	0.06	-0.01	-0.30
SPI_{12} vs. BA	-0.37	–	0.21	0.34*	0.01
SSI_3 vs. BA	–	–	0.16	0.33*	-0.38*
SSI_6 vs. BA	–	–	0.32	0.17	-0.20
SSI_{12} vs. BA	0.02	–	0.38*	0.15	-0.10

Table 3: Correlation among the drought indicators (SPEI, SPI and SSI) and the BA series. Very few fire events are present in the DJF season, thus this season is excluded from the analysis. Besides, very few rain events are present in the JJA season, thus SPEI3 and SPI3 are not calculated for this season. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

	ANNUAL	DJF	MAM	JJA	SON
$SPEI_3$ vs. NF	–	–	-0.41**	–	-0.53***
$SPEI_6$ vs. NF	–	–	-0.30	0.11	-0.53***
$SPEI_{12}$ vs. NF	-0.24	–	-0.18	0.43**	-0.02
SPI_3 vs. NF	–	–	-0.34*	–	-0.16
SPI_6 vs. NF	–	–	-0.20	0.30	-0.16
SPI_{12} vs. NF	-0.20	–	-0.10	0.47**	-0.07
SSI_3 vs. NF	–	–	-0.11	0.04	-0.51***
SSI_6 vs. NF	–	–	0.11	0.31	-0.41**
SSI_{12} vs. NF	0.22	–	0.23	0.27	0.01

Table 4: Correlation among the drought indices (SPEI, SPI and SSI) and the NF series. Very few fire events occur in the winter (DJF) season, thus this season is excluded from the analysis. Besides, very few rain events occur in the summer (JJA) season, thus SPEI3 and SPI3 are not calculated for this season. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3 indicates that the only statistically significant correlations between drought indicators and BA are found in the summer, and are positive. That is, above normal wet condition over the previous 12 months leads to larger fires. This is a possible indication that summer fires in Israel are mainly limited by the structure (availability and connectivity) of the fuel. Note that the summer season is characterized by the smallest values of BA, compared to spring and autumn (Levin and Saaroni, 1999). On the other hand, the absence of negative correlations suggests that fuel flammability is not a limiting factor in Israel for larger fires.

Table 4 reports the correlations between drought and NF. Here, we find negative correlations (that is, dry condition lead to more fires) in MAM and SON and, as for BA, positive in JJA. Thus it seems that different drivers act in the different season. In MAM and SON the number of fires are probably mainly limited by fuel flammability, while in JJA the fire activity is mainly limited by fuel structure (availability and connectivity). These preliminary results suggest that drought conditions in Israel are increasing since 1980 and, in the absence of other drivers, such as fire management, this trend in drought would have led to higher fire hazards in the intermediate seasons.

4 First Conclusions

I spent two weeks in Tel Aviv, Israel, during the month of May of this year (Period: 05/05/2015 to 19/05/2015), in the framework of my STSM grant from the COST Action FP1204. I have been working under the supervision of the Prof. Hadas Saaroni at the Department of Geography and the Human Environment, Tel Aviv University, Israel. My stay, included data collection, field trips (one of them on the most extreme heat and dry day, May 18, when 120 fires were detected) and meeting with local experts has allowed us to start an analysis on the forest fires risk to urban areas and associate weather and climate conditions.

The preliminary analysis suggested that (i) drought conditions are increasing since 1980, (ii) Nevertheless, there is a negative response of forest fires to this increase in the intermediate seasons, when the largest fires develop, attributed mainly to improvement of fire management. However, due to the increase of drought conditions and climate projections for further warming and drying in this region (IPCC 2013), fire risk in Israel is increasing and the research project merits to be pursued in the future.

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