Summer Heat Risk Index: how to integrate recent climatic changes and soil consumption component

Alfonso Crisci[1], Luca Congedo[2], Marco Morabito[1], and Michele Munafò[2]

[1]**IBIMET CNR, Istitute of Biometeorology National Research Council, Firenze, Italy**
[2]**ISPRA – Italian National Institute for Environmental Protection and Research**

ABSTRACT

Face to the urban resiliency two major environmental threats are widely recognized: the increasing summer air temperatures and the soil consumption that affects a large number of city in Italy. The work have the goal to present preliminary the actual Heat Summer Risk defined by using Crichton's Risk Triangle (Crichton, 1999) on the second Italian level of administration (ADM2 - Province). For each administrative unit we have considered as hazard layer the most recent trend of summer air temperature assessed (1980-2014); the exposure layer is individuated by the amount of population living in each province and finally as vulnerable layer the mean degree of soil consumption expressed in percentage was considered. Thanks to these information Crichton's methodology are able to give a quantitative risk value index further classified in five risk class. Data sources was provided by several authoritative institutions : (i) ISPRA (Italian National Institute for Environmental Protection and Research) that provide data about density of soil consumption for 2015 as reported in the Soil Consumption Report 2016; (ii) ECAD (European Climate Assessment & Dataset) that gives detailed historical daily climatic layers (E-OBS 1950-2015 v 13.0); (iii) ISTAT (Italian National Institute of Statistics) that provides the last updates on Italian population data (2016). The results was mapped and presented. All computations was carried out in R-STAT environment by using different library available for Spatial and Trend Analysis. Data and code are released in public repository.

Keywords: Climate changes, Soil consumption, Urban Resiliency, Italy

INTRODUCTION

Following the definition of risk *"The probability of harmful consequences or expected losses resulting from a given hazard to a given element at danger or peril, over a specified time period"* provided by European Commission (Schneiderbauer and Ehrlich, 2004), it is hard do not taken into account the last claims reported by the IPCC 5th Assessment Report (IPCC AR5) concerning the heat wave phenomenon and the summer temperature increase over the Mediterranean area (IPCC, 2015; IPCC and Pachauri, 2015). Is it possible to define a specific "Heat Summer Risk"? The climate literature confirms that Mediterranean area are under pressure in regard to the increase of summer temperature (Diffenbaugh et al., 2007; Bartolini et al., 2008; Kuglitsch et al., 2010; Bartolini et al., 2012). The related phenomena of heat-wave, defined as a prolonged period of excessively hot weather, becomes frequent after 1998 and now are more clearly defined in terms of temperature threshold, spatial and temporal extension (Stefanon et al., 2012; Russo et al., 2015). Heat-waves are the climatic driver of the increase of air summer temperature and the risks associated are potentially significant for human health. When summer temperature are higher than normal climatology many sectors of society and environment are deeply involved. Surely health care sector and work insurance are the first ones impacted by a modified climatic summer heat risk (Morabito et al., 2006; Kovats and Kristie, 2006; McMichael et al., 2006; Morabito et al., 2012). Higher summer temperature are costly and a very good parameter to evaluate its economic impact is the growth of electric consumption that have strong relashionship with high temperature (Le Comte and Warren, 1981; Vardoulakis et al., 2013; Fu et al., 2015). During hot periods air-cooling electrical devices add a considerable peak demand on electrical utility grids (Liang et al., 2016). Undoubtedly the impact of the increasing heat in summers depends in large measure by the quality of city urbanization and the buildings characteristics and in particular their thermal performance (Kapsomenakis et al., 2013; Petralli et al., 2014). Urban design defines spatially, at the city scale, the risk for people(Morabito et al., 2015). Recently it is pointed that exist a significant role played by soil consumption in urban areas as the key factor to determinate the thermal state in Italy (Morabito et al., 2016).The public attention on soil consumption in Italy is grown thanks to the publication of Soil Consumption Report by ISPRA (ISPRA, 2014). This important environmental topic has been largely investigated not only Italy (Munafò et al., 2013a; Salvati, 2013; Munafò et al., 2013b; Salvati et al., 2013) but also in Europe (Hennig et al., 2015) and represent an important factor of vulnerability. Analyzing all claims reported in literature seems important to build a resuming indicator of the heat summer heat risk because its impact is strongly heterogeneous in the urban environment and very complex. A simple Heat Summer Risk Index is proposed in this work and could be suitable to evaluate a spatial representation of this kind of risk useful for land-use decision-makers for promoting an efficient soil sealing management in urban environments.

DATA AND METHODS

Three data source are used in the work: (i) the ISTAT (Italian National Institute of Statistics) population data valid at 01-01-2016 and available at website *http://demo.istat.it/pop2016* 1; (ii) ISPRA (Italian National Institute for Environmental Protection and Research) soil consumption data relative to 2015 at provincial scale expressed as percentage on entire surface 2; (iii) the ECA&D (European Climate Assessment and Datasets) E-OBS mean air temperature climate gridded layers (Haylock et al., 2008) that are available at website: *http://www.ecad.eu/download/ensembles/download.php*.From the ISTAT web data- portal the geographical bounds of Italian provinces are available and are freely available at *http://www.istat.it/it/archivio/124086*. These ones are used to perform a data extraction on E-OBS climate layers obtaining the mean daily air temperature for each Italian provinces covering the period starting from 1980 to 2015. The extraction of data was performed by using R *raster* package (Hijmans, 2015). The average daily summaries were aggregated seasonally (July, August and September) creating a set of 20 annual time series. For each temperature series a non-parametric trend analysis was performed by using R *trend* packages (Pohlert, 2016). For every province it was estimate the annual Sen's slope of summer mean air temperature (Sen, 1968). These values are the temperature's linear trend relative to 1080-2015 and they are scaled to decennial variation (degC/10Years) 3. Having these three data layers the Crichton's methodology has been applied to calculate the Summer Heat Risk Index (SHRI) working only on the normalized data. The normalization was used to obtain the layers of hazard (Summer Temperature trend), exposure (Population) and vulnerability (percentage of soil consumption) on the same scale (0 to 1) by dividing each value of an individual layer by the range of variability. The following step was the combination of the normalized layers through a weighting procedure. More general expression 1 and SHRI formulation 2 are here presented.

$$Risk = (0.5 * Vulnerability + 0.5 * Exposure) * 0.5 + Hazard * 0.5 \tag{1}$$

$$SHRI = (0.5 * Norm\_Perc\_Soil + 0.5 * Norm\_Population) * 0.5 + Norm\_T\_trend * 0.5 \tag{2}$$

To avoid subjective manipulation, all weightings were kept equal. Population layer are linked to Soil Consumption so the exposure and vulnerability layers were combined in a single “exposed and vulnerable” layer (each weighted at 50%) that which was then combined with the hazard layer (weighted at 50%). SHRI varies from 0 and 1 and represents a risk evaluation face to the hazard considered. The final province-specific mapping visualization was created by splitting the SHRI values into five equal-risk levels: very low ($SHRI \leq 0.2$), low ($0.2 < SHRI \leq 0.4$), moderate ($0.4 < SHRI \leq 0.6$), high ($0.6 < SHRI \leq 0.8$), and very high ($SHRI > 0.8$). Graphical environment for maps was done by using JavaScript Leaflet Library available trough the R *leaflet* package (Cheng and Xie, 2016).The code and repository is available at website *https://github.com/alfcrisci/ogrs_2016_SHRI_paper*.

RESULTS AND DISCUSSION

The final map 4 describe a well-defined pattern of the Summer Heat risk existing actually in Italy. The provinces with the greatest SHRI were those including the largest cities such as Rome, Naples and

Milan. These areas are more localized in Italian territory. Many other northern and southern areas also exhibited a high SHRI level. Central areas, with the exception of Rome, and mountain areas (on the Alps and Apennines) seems less vulnerable, showing a general low level of SHRI. SHRI Italian pattern has deep implications for policy making, suggesting that each city's climate and soil consumption, must be considered into climate change mitigation strategies (Fu et al., 2015).The significant trends in climate variables as temperatures due tell us that urban areas are facing a strong adaptation imperative (Carter et al., 2015).

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FIGURES

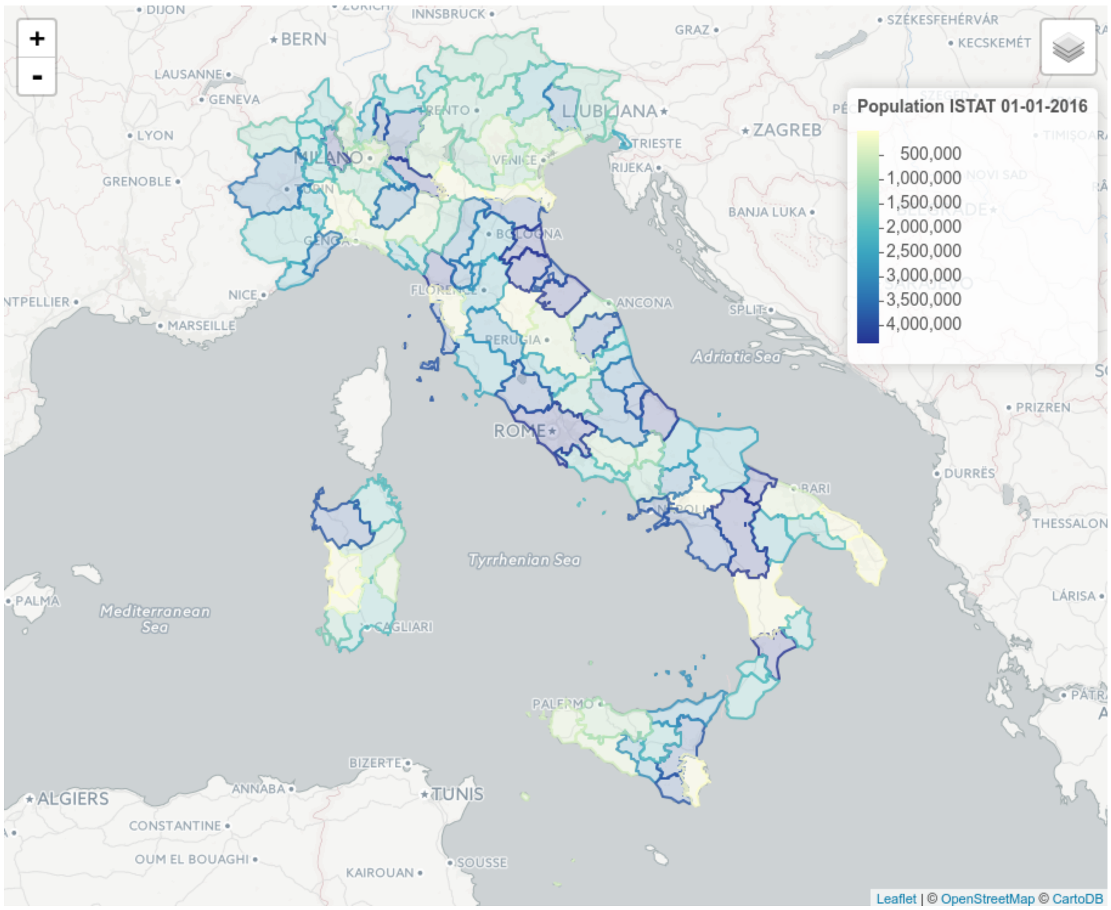

Figure 1. ISTAT Italian Population data by Province

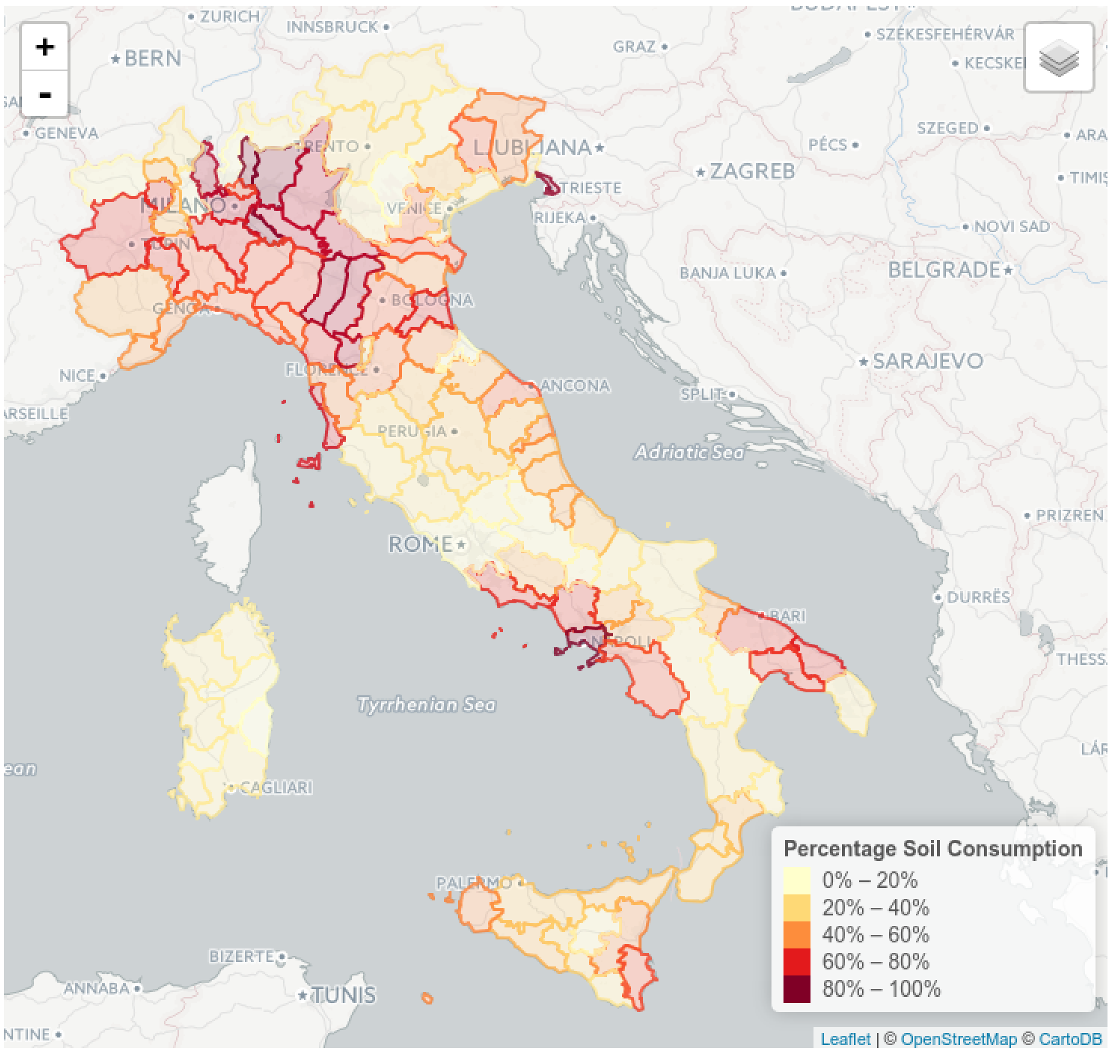

Figure 2. ISPRA Percentage of soil consumption by Province

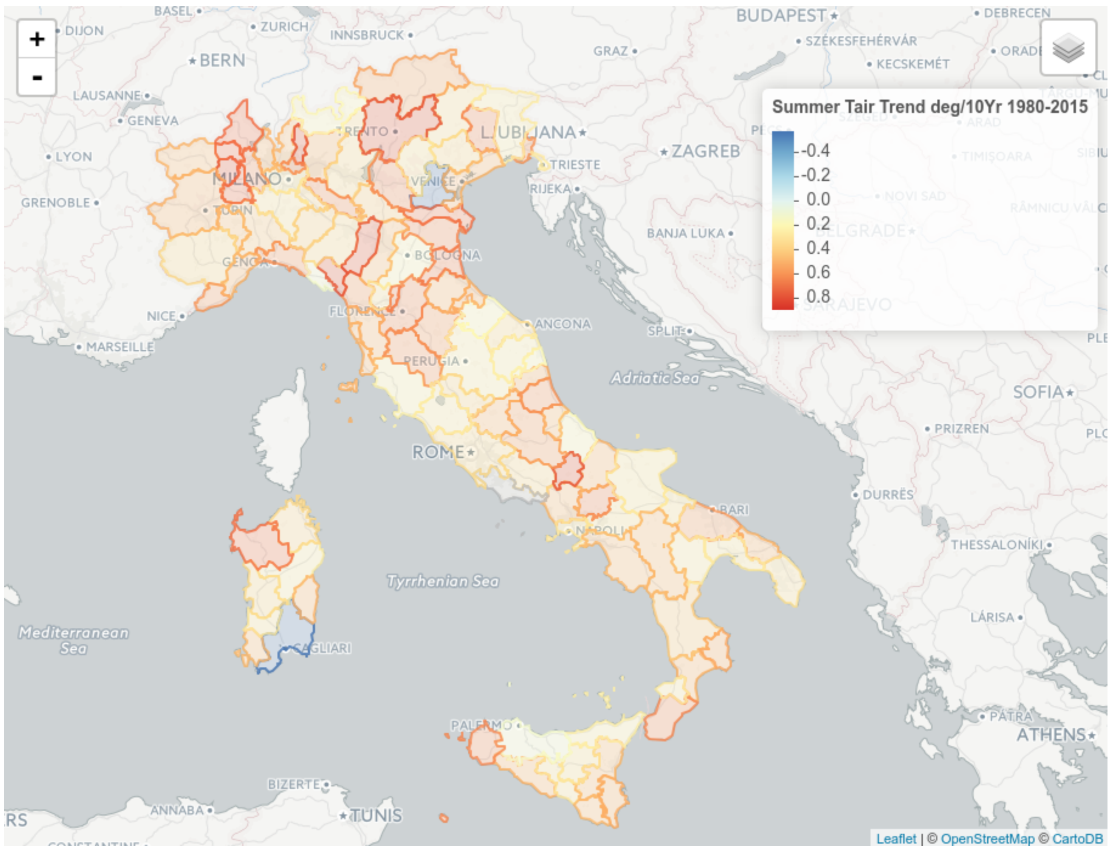

Figure 3. Summer mean air temperature trend by Province 1980-2015

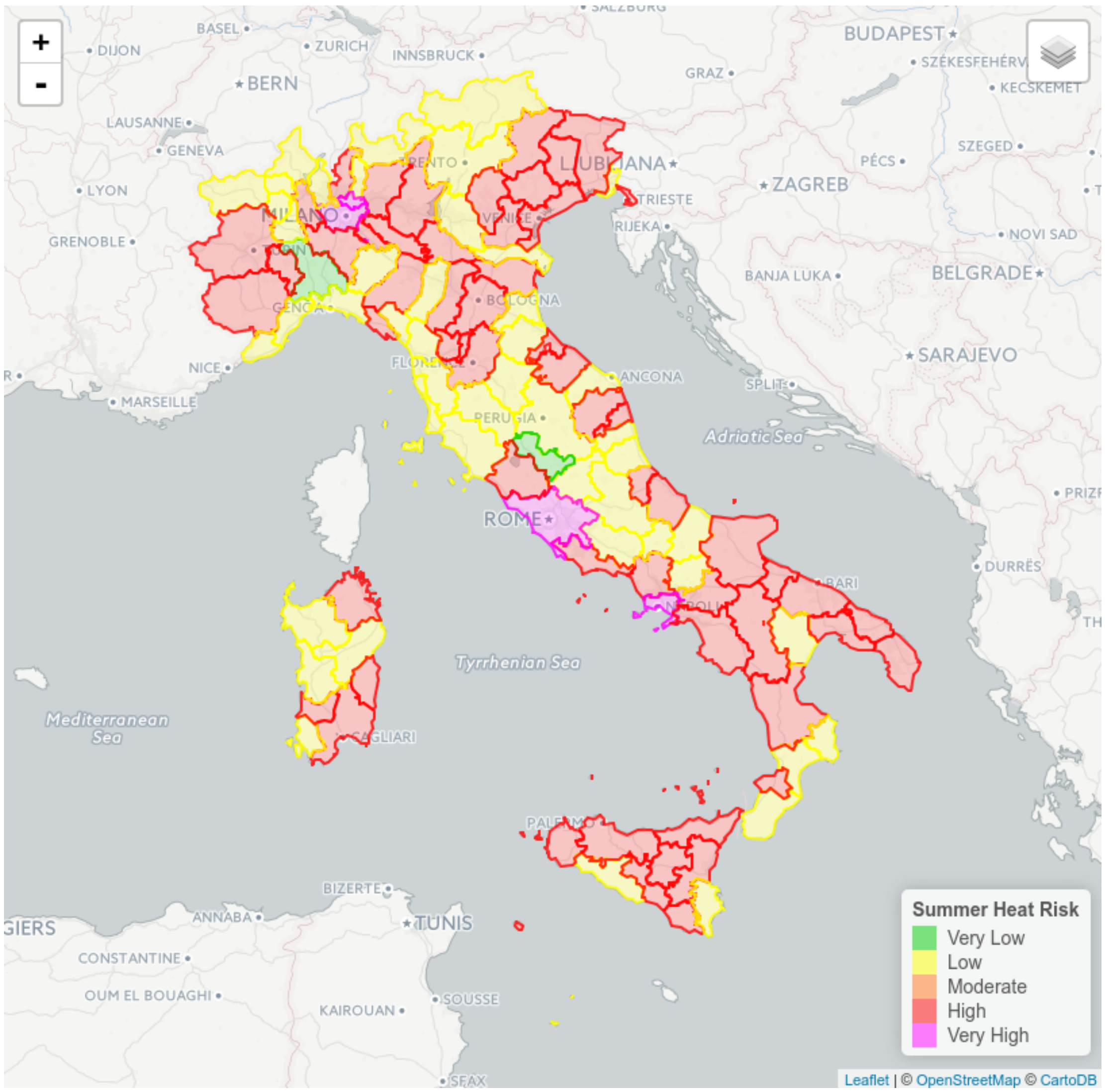

Figure 4. Summer Heat Risk Index (SHRI) classes by Province