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Abstract: *Thermal comfort in urban environment is one of the major issue that future planning authorities will argue in the next years. It is well known that urban design at the micro-scale can influence human thermal comfort. In the last few years many authors have underlined the effect of the presence of green or high albedo materials on thermal comfort together with pedestrian heat stress. But it is not easy to translate the climate language into planning tools to be applied by urban planners. This study aims at quantifying the amount of hours, during the summer period, of thermal discomfort in the city of Florence in order to support planners to identify the needs of the city. Another purpose is to investigate the relationship between hours of thermal comfort and percentage of green area in the surroundings. Three biometeorological indices widely used to express thermal comfort in Italy (Steadman Apparent Temperature Index, Humidex, and Thom Discomfort Index) were calculated in 15 places in Florence urban area during Summer 2010. Results of this study quantify the difference in terms of thermal comfort that it is possible to find during the summer period in the city of Florence according to the biometeorological indices used, as well as the benefits in terms of thermal comfort of a 10% increase of green in an area of 250 m radius.*
Keywords: *biometeorology, thermal comfort, urban green, microclimate, biometeorological indices.*

Riassunto: *Il benessere termico in ambiente urbano rappresenta uno dei temi principali che gli amministratori e gli urbanisti dovranno affrontare nei prossimi anni. È ormai noto, infatti, che il disegno delle infrastrutture urbane può influenzare il benessere termico della popolazione. Sono infatti numerosi gli studi che a livello internazionale hanno sottolineato l'importanza delle aree verdi o dell'uso di materiali con elevati valori di albedo sul benessere/disagio termico sui pedoni. Ma il trasferimento delle conoscenze e del linguaggio climatico in strumenti utili ai pianificatori è tutt'oggi relativamente difficile. Questo lavoro mira a quantificare le ore di disagio termico durante il periodo estivo nella città di Firenze, al fine di fornire informazioni utili che possano supportare i pianificatori e gli amministratori nell'identificazione delle caratteristiche e delle esigenze della città. Un secondo scopo è quello di valutare la relazione tra ore di disagio termico estivo e presenza di aree verdi nelle vicinanze. A tal fine, in 15 zone della città di Firenze, sono state quantificate le ore di disagio termico registrate durante l'estate 2010 utilizzando tre indici biometeorologici comunemente usati in Italia per la valutazione del disagio termico estivo, l'Apparent temperature di Steadman, l'indice Humidex e l'indice di Thom. I risultati sono utili a quantificare le differenze, in termini di benessere/disagio termico, che si possono registrare durante il periodo estivo all'interno della città di Firenze, e l'effetto che un aumento del 10% di area verde in un'area di 250 metri di raggio può determinare in termini di benessere termico.*
Parole chiave: *biometeorologia, benessere termico, verde urbano, microclima, indici biometeorologici.*

Nomenclature of term used: AT: Apparent Temperature Index (°C); H: Humidex (°C); DI: Thom Discomfort Index (°C); T: Air temperature (°C); RH: relative humidity (%); TW= wet bulb temperature (°C); Pa= vapor pressure (kPa).

1. INTRODUCTION

The temperature difference between urban and rural areas has been investigated all over the world (Oke, 1976; Bottyan *et al.*, 2005; Unger, 2004; Yan *et al.*, 2010). Several studies have evidenced that urban morbidity and mortality in summer are becoming increasing problems due both to the high temperatures that can occur during summer in the urban environment and to the high population density (Gosling *et al.*, 2009; Petralli *et al.*, 2012; Kilbourne, 1997). As Basu and Samet (2002) state, people living in urban areas have a higher risk of death during heat waves than those living in rural areas due to the Urban Heat Island Effect. Furthermore, the more temperature increases, the more consumption of energy increases since it becomes necessary to cool indoor spaces for a better comfort. This causes several effects like a higher demand for electricity, higher pollution, higher urban footprint and finally reflects also in human discomfort and health problems (Hassid *et al.*, 2000; Santamouris *et al.*, 2001; Cartalis *et al.*, 2001; Santamouris *et al.*, 2007; Stathopoulou *et al.*, 2008). In the last few years, many authors have focused more attention to the intra-urban air temperature difference respect to that one between urban and rural areas (Arnfield,

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2003; Coutts et al, 2007; Unger, 2004; Eliasson, 1996; Holmer *et al.* 2007; Petralli *et al.*, 2011; Chen *et al.*, 2012). Similarly to the urban-rural difference, the intra-urban thermal difference is stronger during calm and sunny days as well as during the evening (Eliasson, 1996; Petralli *et al.*, 2011). In Florence (Italy), during summer period, a difference of 12 summer days (days with maximum temperature higher than 25 °C) and of 32 tropical nights (days with minimum air temperature higher than 20 °C) was found between the coolest and the hottest areas of the city (Petralli *et al.*, 2011). The effects of the intra-urban thermal differences can have evident applications in several fields of study, such as biometeorology, urban planning, plant phenology and aerobiology. According to these differences, it is possible to identify areas of the city characterized, for example, by advanced flowering, or at higher health risk during summer heat waves or cold spells (Neil *et al.*, 2014; Massetti *et al.*, 2015; Loughnan *et al.* 2012; Kestens *et al.*, 2011). Other effects of the intra-urban thermal variability are related to thermal comfort (Chen and Ng, 2012). The topic of urban thermal comfort is particularly attractive by experts from several disciplines, such as urban planners, urban designers, architects, biometeorologists and physicians (especially epidemiologists and physiologists). Among the factors that affect urban heat island and the intra-urban thermal distribution there are the high buildings density, the use of materials that absorb solar radiation, the scarcity of green areas as well as the production of anthropogenic heat (Oke *et al.*, 1991). Thus, thermal comfort is particularly influenced by urban design at the micro-scale (Vanos *et al.*, 2012; Holst and Mayer, 2011; Petralli *et al.*, 2014; Massetti *et al.*, 2014): the presence of parks, the sky view factor and the orientation of the street canyon can influence micrometeorological variables that control the human thermal sensation, such as air temperature, relative humidity, wind speed and mean radiant temperature (Vanos *et al.*, 2012; Holst and Mayer, 2011; McGregor, 2012; Johansson and Emmanuel, 2006). Lindberg and Grindmond (2011) confirm that through the increase of green areas and vegetation it may be possible to improve citizens' comfort during summer heat waves. In addition, the increase of thermal comfort can be achieved by reducing surface temperatures through the use of elements such as trees and buildings (Shashua-Bar *et al.*, 2011; Spronken-Smith and Oke 1999). Relative to this, many studies state that even different vegetation types and vegetation densities have diverse effects on thermal comfort (Charalampopoulos *et al.*, 2012; Cohen *et al.*, 2012; Lin *et al.*, 2008; Potchter *et al.*, 2006; Ali-Toudert and Mayer 2005).

This study deals with urban human-biometeorology on the micro-scale aiming at quantifying the intra-urban thermal comfort variability of Florence by using a network of air temperature and relative humidity sensors. Furthermore, it aims at finding a relationship between this variability and the presence of green areas, in order to study the effect of vegetation on thermal comfort within urban environment.

2. METHODS

2.1. Study area and meteorological data

A network of air temperature and relative humidity sensors (HOBO® PRO series Temp/RH Data Logger, Onset Computer Corporation, Pocassette, MA, USA; operating range T:-30-50 °C, RH:0-100%, resolution: 0.2 °C between 0-40 °C) with naturally ventilated solar radiation shields (RS1-HOBO® PRO accessories) was set up in the city of Florence since 2004 (Lat: 43.77; Long: 11.26; elevation 50 m asl). The city lies on a plain in the central part of Italy to the southwest of the Apennine mountains and it is characterized by a sub-Mediterranean climate with hot and dry summer, mild and quite wet winter, and wet autumn and spring. Sensors were located in the urban area at a height of approximately 2 m to analyze thermal conditions at pedestrian level, and more than 2 m away from buildings in order to obtain representative measurements in built-up areas (Oke 2004).

Data were collected every 15 minutes from each station and hourly averaged values were calculated. All the analyses were made on data collected according to the WMO standard. Air temperature and relative humidity data series completeness were checked, consequently, only 15 stations that had no missing data in both parameters in the study period (from the 1st of June to the 31st of August 2010) were selected (Fig. 1).

2.2. Biometeorological indices and percentage of green

In the last century an active research on how to define thermal comfort together with how to grade thermal stress has been carried out (Blazejczyk *et al.*, 2012). These efforts have resulted in a large number of indices that can be divided into three groups: rational indices, based on calculations involving the heat balance equation; empirical indices, based on objective and subjective strain; direct indices, based on direct measurements of environmental variables. In this study, three direct bio-

Fig. 1 - Florence Municipality map and location of the 15 air temperature and relative humidity sensors.
Fig 1 - Carta della città di Firenze con localizzazione dei 15 sensori di temperatura ed umidità dell'aria utilizzati nello studio.

meteorological indices have been used to assess the effects of air temperature and relative humidity on human discomfort conditions. These indices are the most commonly used in Italy for the evaluation of discomfort during summer: Apparent Temperature Index (AT), Humidex (H) and Thom Discomfort Index (DI).
The AT, developed by Steadman in 1979 and subsequently revised in 1994 (Steadman, 1979; Steadman, 1994), was the first one used by the U.S. National Weather Service to predict heat discomfort conditions in large areas. The risk categories specified by the National Weather Service are shown are shown in Tab. 1. This biometeorological index was selected because it is used by the regional biometeorological forecast service of Tuscany (www.biometeo.it) and a recent study (Morabito *et al.*, 2014) evaluated it as the best predictor for all-cause very-elderly mortality risk in Florence. In this study it is calculated considering the effect of air temperature and vapor pressure:
$AT = 0.89\ Ta + 3.83\ Pa - 2.56$
Where AT= Apparent Temperature; Ta= air temperature (°C) and Pa= vapor pressure (kPa)

Class	AT	Possible heat disorders for people in higher risk groups
0	AT< 27	Comfort
1	27≤AT<32	Caution — fatigue is possible with prolonged exposure and activity. Continuing activity could result in heat cramps.
2	32≤AT<41	Extreme caution — heat cramps and heat exhaustion are possible. Continuing activity could result in heat stroke.
3	41≤AT<54	Danger — heat cramps and heat exhaustion are likely; heat stroke is probable with continued activity.
4	AT≥54	Extreme danger — heat stroke is imminent.

Source: NOAA (http://www.srh.noaa.gov/ffc/?n=hichart).

Tab. 1 - Classes of comfort/discomfort: Apparent Temperature Index.
Tab 1 - Classi di benessere/disagio termico per l'indice Apparent Temperature.

The Apparent Temperature Index is valid for air temperatures above 20 °C and its values are categorized due to possible heat disorders in people (Blazejczyk *et al*. 2012).

The Humidex Index was developed in 1965 and revised in 1979 by Masterson and Richardson (1979). It is still used in Canada for the weather forecast during summer season. It gives a measure of the perceived temperature combining the effect of excessive humidity and high temperature (Conti *et al.*, 2005).
The risk categories are shown in Tab. 2 and the index is calculated as follows:
$H = Ta + (0.5555 \times (Pa – 10))$
Where H= Humidex; Ta= air temperature (°C) and Pa= vapor pressure (kPa).

Thom Discomfort Index, proposed by Thom e Bosen (1959), provides a measure that describes the degree of discomfort conditions at various combinations of temperature and humidity (Mather, 1974). It is based on both dry and wet bulb temperatures and it is currently used in Central Italy (Emilia-Romagna Region) during summer season by the Meteorological Service (Zauli Sajani *et al.*, 2002). Risks categories are shown in Tab. 3 and it is calculated as follows:
$DI = 0.4 \times (Ta + Tw) + 4.8$
Where DI= Discomfort Index; Ta= air temperature (°C) and TW= wet bulb temperature (°C) .

Green Cover Ratio (GCR), defined as the percentage of the area covered by any kind of vegetation against the total area (%), was used to analyze the effect of vegetation during the summer season. GCR was calculated by using geographically referenced data integrated by visual classification of vegetated areas (ESRI®ArcMap™ 9.3.1) performed on orthoimages provided by Florence Municipality (scale 1:10000, pixel resolution: 0.50 m x 0.50 m). Within this study the GCR was calculated on a buffer area of 250 m radius, centered on each sensor.

2.3. Statistical analysis
To analyze the influence of green areas on summer air temperatures within the urban environment, the relationship between average seasonal values of discomfort indices (AT, H, DI), and GCR were calculated by linear regression. For each analysis, results were expressed by coefficient of determination (R^2) and significance level p. All the statistical analyses were performed by using SPSS for Windows version 17.

3. RESULTS
Summer mean and standard deviation of minimum, mean and maximum daily temperature and relative humidity for each sensor are presented in Tab. 4. Mean summer thermal difference between the coolest and the hottest area of the city of Florence reached 2.9 °C, 2.7 °C and 3.1 °C respectively for

Class	H	Degree of comfort
0	H<27	Comfort
1	27≤H<30	Some discomfort
2	30≤H<40	Great discomfort
3	40≤H<55	Dangerous
4	H≥55	Very dangerous (heatstroke imminent)

Tab. 2 - Classes of comfort/discomfort: Humidex (H).
Tab. 2 - Classi di benessere/disagio termico per l'indice Humidex (H) et al. *(2002).*

Class	DI	Degree of discomfort
0	DI < 21	No discomfort
1	21 ≤ DI < 24	Less than half population feels discomfort
2	24 ≤ DI < 27	More than half population feels discomfort
3	27 ≤ DI < 29	Most population feels discomfort and deterioration of psychophysical conditions
4	29 ≤ DI < 32	The whole population feels an heavy discomfort
5	DI ≥ 32	Sanitary emergency due to the very strong discomfort which may cause heatstrokes

Source: Thom and Bosen (1959)

Tab. 3 - Classes of comfort/discomfort: Thom Discomfort Index (DI).
Tab. 3 - Classi di benessere/disagio termico per l'indice di Thom (DI).

Station name	Tmin (°C)	Tmean (°C)	Tmax (°C)	RHmin (%)	RHmean (%)	RHmax (%)	Green %
FI_04	17.8 ± 2.8	23.1 ± 3.2	28.9 ± 4	46 ± 14.4	70.8 ± 11	92.4 ± 7.2	81
FI_09	16.9 ± 2.7	22.5 ± 3.2	28.4 ± 4	38.2 ± 18.3	71.9 ± 13.2	98.6 ± 5.3	84
FI_18	18.6 ± 2.8	23.6 ± 3.1	29 ± 3.8	42.1 ± 14.3	67.6 ± 11.7	89.4 ± 8.6	10
FI_19	19.8 ± 3	25.2 ± 3.4	30.4 ± 3.9	35.5 ± 14.7	63.5 ± 13.9	92.9 ± 10.8	31
FI_21	19.5 ± 3.1	25.1 ± 3.3	31.5 ± 4.2	34.1 ± 11.6	57.8 ± 9.8	79.3 ± 9	25
FI_22	19 ± 2.9	24.5 ± 3.2	30.2 ± 3.9	41.1 ± 14.8	68.7 ± 12	93.5 ± 8.5	29
FI_24	17.5 ± 3	23.6 ± 3.1	29.7 ± 3.8	51 ± 23.4	84 ± 11.1	100 ± 0	43
FI_32	19.7 ± 2.9	24.9 ± 3.2	30.5 ± 3.8	43.2 ± 14.6	70.7 ± 12.5	95.6 ± 8.7	24
FI_33	19.8 ± 2.9	24.8 ± 3.2	30.1 ± 3.9	36.7 ± 12.8	59.8 ± 10.8	80.9 ± 9.2	10
FI_34	16.9 ± 2.7	22.9 ± 3	29.4 ± 3.9	42.7 ± 18.8	79.3 ± 10.4	99.9 ± 1.2	73
FI_35	17.4 ± 2.7	23.5 ± 3.2	30.2 ± 4.2	33.8 ± 17	65.4 ± 13.7	94.4 ± 8.1	78
FI_37	18.6 ± 2.7	23.6 ± 3.1	28.8 ± 3.6	45.7 ± 16.2	73.2 ± 11.7	95.7 ± 6.2	80
FI_38	18.4 ± 2.9	24 ± 3.3	30.1 ± 4.1	39.3 ± 13.5	64.8 ± 10.8	87.3 ± 8	60
FI_40	17.1 ± 2.7	23.3 ± 3.1	30 ± 4.1	42.1 ± 14.5	72.1 ± 10.8	96.3 ± 6.2	44
FI_45	17.9 ± 2.8	23.6 ± 3.1	29.4 ± 3.8	42.4 ± 12.4	67.7 ± 9.9	91.4 ± 7	51

Tab. 4 - Minimum (Tmin, RHmin), Average (Tmean, RHmean) and Maximum (Tmax, RHmax) air temperature (T, °C) and relative humidity (RH, %), expressed as mean ± standard deviation and the percentage of green (Green) calculated on a buffer area of 250 m radius, centered on each sensor (%).
Tab. 4 - Valori minimi (Tmin, RHmin), medi (Tmean, RHmean) e massimi (Tmax, RHmax) di temperatura dell'aria (T, °C) e umidità relativa (RH, %), espressi come media ± deviazione standard, e percentuale di aree verdi (Green) presenti in un'area di 250 metri di raggio centrata su ogni stazione (%).

minimum, mean and maximum temperature. Percentage of green area varies between 10 % and 84%. The mean number of hours of discomfort during summer 2010 (total number of hours= 2208) were respectively 891 using Steadman, 1485 using Humidex and 1605 using Thom indices (Tab. 5).The difference between maximum and minimum discomfort among the sites varied considerably according to the considered index reaching a maximum of 541 discomfort hours for Steadman, 464 for Humidex and 402 hours for Thom (data not shown).

The relationship between GCR and each discomfort index was always significant (AT: R2=0.272, P<0.05; H: R2=0.300, P<0.05; DI: R2=0.396, P<0.05). The effect of the presence of green areas

Classes	AT	H	DI
0	1316.93 ± 152.81	722.53 ± 138.83	603.33 ± 122.85
1	531.86 ± 62.51	423.8 ± 45.93	815.33 ± 59.75
2	359.2 ± 118.29	985.26 ± 126.86	627.53 ± 83.57
3		76.4 ± 77.13	152.4 ± 61.44
4			9.4 ± 16.25
5			
Total discomfort	891.06 ± 152.81	1485.46 ± 138.83	1604.66 ± 122.85

Tab. 5 - Number of comfort/discomfort hours (expressed as mean ± standard deviation) of each biometeorological indices (AT Steadman, Humidex and Thom) in summer.
Tab. 5 - Ore di benessere/disagio termico (espresso come media± deviazione standard) di ogni indice biometeorologico: Apparent Temperature (AT), Humidex (H) e Indice di Thom (DI) durante il periodo estivo.

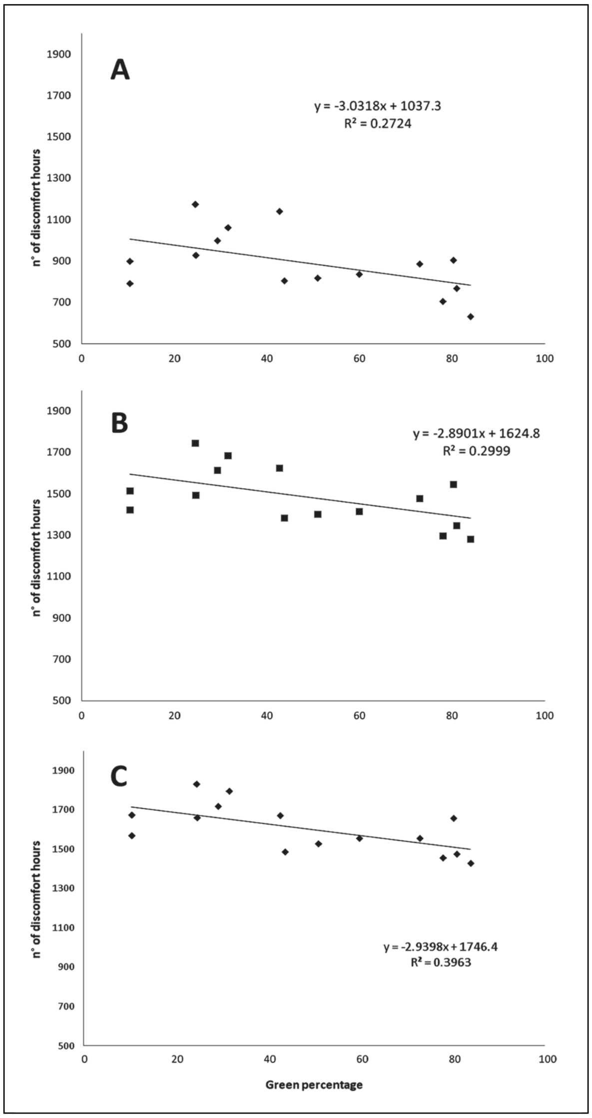

Fig. 2 - Correlation between the percentage of green and the total discomfort hours calculated with the following indices: Steadman (A), Humidex (B) and Thom (C).
Fig. 2 - Correlazione tra percentuale di aree verdi e ore totali di disagio termico calcolate applicando l'indice AT (A), l'indice Humidex (B) e l'indice di Thom (C).

on thermal comfort was the same for each index: a 10 % increase of green area can cause a discomfort reduction of approximately 30 hours during the summer period in Florence.

The diurnal variation of all the indices (mean ± standard deviation) was also observed during one of the hottest day of summer 2010 in Florence (10th July 2010) (Fig. 3A, 3B and 3C). Thermal comfort variability among the sites is given by the standard deviation varying between 1.1 °C and 2.8°C (AT), 1.5 °C and 3.3 °C (H) and 0.6 °C and 1.6 °C (DI). On average all the sensors recorded values higher than the

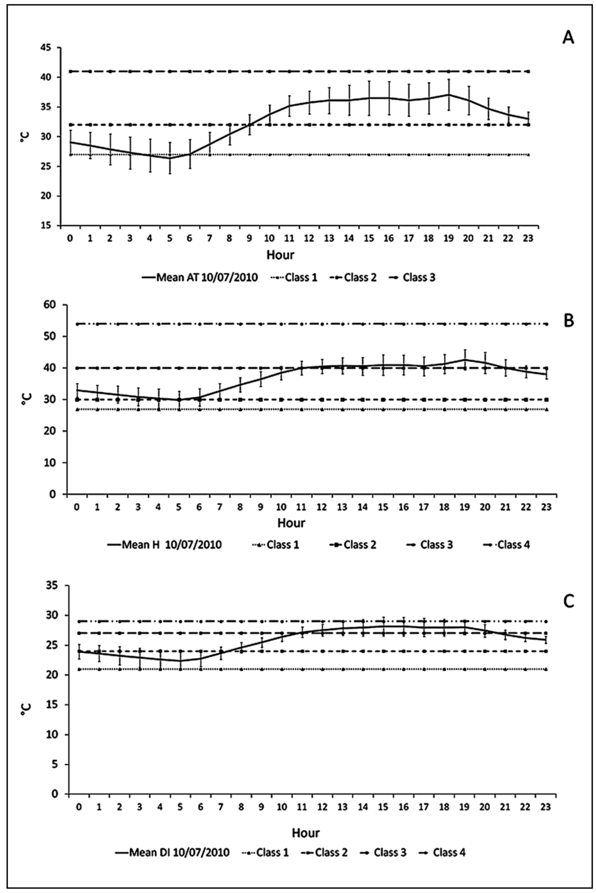

Fig. 3 - Mean and standard deviation of hourly: **A** - Steadman index (AT) of all the sensors in 10/07/2010 and AT discomfort classes: caution (dashed and dotted line), extreme caution (dashed line) and danger (solid line); **B** - Humidex index (H) of all the sensors in 10/07/2010 and H discomfort classes: some discomfort (dashed line), great discomfort (dotted line), dangerous (dashed and dotted line) and very dangerous (solid line); **C** - Thom index (DI) of all the sensors in 10/07/2010 and DI discomfort classes: less than half population feels discomfort (dashed line), more than half population feels discomfort (dotted line), most population feels discomfort (dashed and dotted line) and the whole population feels an heavy discomfort (solid line).
Fig. 3 - Valori medi (deviazione standard) dei valori orari di: indice AT di Steadman calcolato in tutti i sensori nella gionata del 10/07/2010 e classi di disagio termico dell'indice AT (grafico A) (cautela- linea tratteggiata e punteggiata, estrema cautela- linea tratteggiata e pericolo- linea continua); indice Humidex calcolato in tutti i sensori nella gionata del 10/07/2010 e classi di disagio termico dell'indice Humidex (grafico B) (qualche disagio - linea tratteggiata, forte disagio -linea tratteggiata, pericolo - linea tratteggiata e punteggiata e pericolo elevato - linea continua); indice di Thom calcolato in tutti i sensori nella gionata del 10/07/2010 e classi di disagio termico dell'indice di Thom (grafico C) (meno della metà della popolazione sente disagio - linea tratteggiata, più di metà della popolazione sente disagio - linea punteggiata, la maggior parte della popolazione sente disagio – linea tratteggiata e punteggiata, e tutta la popolazione sente un forte disagio - linea continua).

comfort threshold for all the 24 hours, except for AT Steadman where no discomfort was registered between 2 a.m. and 6 a.m in the greenest sites of the city.

4. DISCUSSION

The major findings of this study are:

1. The quantification of the total summer amount of hours of thermal discomfort of Florence (Italy).
2. The application of three different and widely used comfort indices (AT, H and DI) shows a strong thermal variability among urban areas of Florence; this variability can result in a difference of 541 discomfort hours for Steadman, 464 for Humidex and 402 hours for Thom between the hottest and the coolest site during summer season.
3. Percentage of green surrounding the station affects significantly thermal comfort. A 10 % increase of green could avoid 30 hours of summer discomfort.
4. The effect of the presence of green areas on thermal comfort was almost the same for each index analyzed.

The bioclimatic situation and thermal comfort is one of the major issue that future planning authorities will argue. In the last few years many authors have underlined the effect of the presence of green or high albedo materials on urban air temperature as well as Urban Heat Island (UHI) mitigation (Taha, 1997; Susca *et al.*, 2011).The color of surfaces influences surface temperatures by affecting the albedo of a material: darker surfaces have low albedo and adsorb more solar radiation, while lighter surfaces have higher albedo and reflect more sunlight (Sailor, 1995). On the other hand, the presence of green contribute to reduce air temperature in urban environment with shade and evapotranspiration (Taha, 1997). A recent review of the evidence of the use of green to cool cities confirms the presence of lower temperatures inside and near the urban park than a non-green site, but also confirms the need of a higher number of empirical research to demonstrate the cooling effect of green areas (Bowler *et al.*, 2010).

As regard green areas, it is important to distinguish if the green area is covered by trees or by grass: in the first case, the effect on thermal comfort is positive during the day because of the shade provided by trees crowns reducing the amount of solar radiation that reaches human body; while, if it is covered by grass, the positive effect on thermal comfort is stronger during nighttime because of the strong heat loss of grass after the sunset (Bowler *et al.*, 2010; Petralli et al, 2014). As regard thermal comfort, the use of trees and albedo material in urban environment have opposite effects (Errel *et al.*, 2014; Shashua-Bar *et al.*, 2010; Noro et al, 2014a; Noro *et al.*, 2014b). Errel and collaborators (2014) evidence that the use of high-albedo materials in urban canyon surfaces lowers air temperature, but at the same time increases the radiant loads, so that pedestrian thermal comfort is reduced. The results of our study quantify the difference in terms of thermal comfort that is possible to find during summer period in Florence, as well as the benefits in terms of thermal comfort of an increase of green. Results related to the quantification of the total summer amount of hours of thermal discomfort of the city of Florence is linked to the index used and to the site of data collecting. The difference in the amount of discomfort hours according to the index used is very high, and is linked to the discomfort scale associated to each index. The differences between thermal indices is investigated all over the World, especially as regards the effectiveness of each index as best predictor for heat-related morbidity and mortality (Morabito *et al.*, 2014). The choice of the index results fundamental: it should be representative of the discomfort felt by citizen living in the study area, or be representative of the effects that discomfort has on their health. In this way it is possible to spread an information that can be widely used and understood by the whole population , by the local authorities and by policymakers. As regard the quantification of thermal discomfort of Florence, only one year of data is not sufficient to give a representative information about the quantification of thermal discomfort of the city, so in future studies a higher number of years will be included. On the contrary, it is possible to argue about the intra-urban thermal comfort variability observed in Florence. This variability is mainly linked to the presence of green areas, in fact, a 10 % increase in green space in an area of 250 m radius, leads to a reduction of about 30 hours of thermal discomfort in the entire summer period in the same area of the city. But local urban temperature may be affected by other urban parameters, such as street aspect ratios (H/W) as well as the sky view factor (Oke, 1988), so it will be interesting to investigate the relationship between thermal comfort and other urban parameters in future studies.

5. CONCLUSIONS

This study represents a first step towards the analysis of the quantification of summer thermal discomfort for a city together with the evaluation of the intra-urban variability of this parameter. Both those findings can be used by planners and policy-makers in order to understand the needs of the city in terms of thermal stress mitigation. While the quantification of the effect of an increase of 10 % in an area of 250 m radius could be used as a planning indicator for the quantification of the benefits that an urban transformation can bring to local population. Future studies on this topic could lead to the elaboration of urban maps of thermal comfort, that can be an useful tool to identify the areas of the city that need to be transformed to implement local wellbeing of citizens.

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